Household Refrigeration

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Household Refrigeration

A COMPLETE TREATISE ON THE PRINCIPLES, TYPES, CONSTRUCTION, AND OPERATION OF BOTH ICE AND MECHANICALLY COOLED DOMESTIC REFRIGERATORS, AND THE USE OF ICE AND REFRIGERATION IN THE HOME

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PREFACE TO THE FIRST EDITION

In developing this work on "Household Refrigeration," the first of the kind published, the author has endeavored to present a subject in its broadest sense.

Attention has been given to the production of refrigeration for any household or domestic purpose by both ice and mechanically cooled refrigerators. The work consists of a treatise on the principles, types, construction and operation of both ice and mechanically cooled refrigerators, including therein certain considerations on the use of ice and refrigeration in the home.

It is believed that this work will not only be found to be interesting and instructive to designers, manufacturers, dealers, and distributors, of both ice and mechanically cooled refrigerators, but also will be of interest to the householder, who employs refrigeration in either of the aforementioned systems.

The author has drawn extensively on his experience as a refrigeration engineer for material for this work. However, in the many instances, he has made use of the work of others, for which proper credit has been given. The author desires to gratefully acknowledge the assistance which has been extended to him by various associations, publishers, manufacturers, and others, during the preparation of the subject matter of this book.

H. B. Hull.

PREFACE TO THE THIRD EDITION

The industry of Household Refrigeration has made great strides in the interim since the preparation of the first and second editions of this work.

The use of the small refrigerating machine in homes is rapidly increasing each year.

The use of ice in the home is also gradually increasing.

The seasonal character of sales of both household refrigerating machines and ice is gradually becoming less marked.

Many countries in Europe are demanding ice and household refrigerating machines to assure proper food preservation in the home.

This edition contains descriptions of the latest models of both compression and absorption type household refrigerating machines and also includes recent improvements in refrigerator construction.

H. B. Hull,
Dayton, Ohio.

October, 1927.

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FOREWORD.

The problem of preserving food collected during times of plenty, for use when the source of supply fails, has been practiced by man from even the remotest ages. Among primitive races, food preservation was essential to avoid famine. In the modern civilized countries, the preservation of food is an important factor in maintaining a balance between the demand and supply for perishable foods. There is a special need of preservation in order to transport food to the large cities.

Chemical processes of animal and vegetable tissue actively continue in these foods even after the more obvious evidences of life has gone. Fruits ripen, grains mature, starches become sugars, flavors develop, and meat becomes tender. These changes are desirable and nutritively beneficial.

There are numerous artificial methods employed to restrain the activity of these processes in foods. The most important is by refrigeration or cooling. Some other methods are by drying, dehydrating, smoking, pickling, curing, preserving, and cooking.

Refrigeration is the method of food preservation which causes a minimum of alteration of the desirable food properties. The natural freshness and flavors are retained without abstracting moisture, and there is a minimum change in the physical, chemical, or nutritive qualities of the food.

Refrigeration was first used by the Egyptians, Greeks, and Romans, who cooled their wines and water in crude vessels which extracted some of the heat from the liquids through evaporation.

The first methods of preserving food by cooling were very crude—a hole in the ground or a stream of water served this purpose.

In the early part of the nineteenth century, the ice box came into use. Natural ice was placed in the ice compartment. The melting of the ice produced a circulation of cold air which cooled the foods. This was a great improvement over previous methods of storing perishable foods.

Ice of the winter months was stored for this use in specially constructed buildings, located near the pond or lake supplying it.

The supply of natural ice was very uncertain. Transportation was difficult and ice was only available to limited localities.

The next important step in household refrigeration was the use of manufactured ice. Active work in the development of machines for producing ice in a commercial way was carried on from 1830-1870. The success of these machines permitted their use in even the warmest climates. In addition there were difficulties in transporting natural ice any great distance from its source. In regard to manufactured ice, the large loss in melting during months of storage and the time of transportation could be saved. The quality of the water used for making ice could be better controlled. The supply was more certain and could be regulated to meet the demand.

In addition to the increased use of manufactured ice, some improvement in the construction of household refrigerators was made. Better insulation was used, more sanitary linings and better air circulating systems designed. The temperature in the food compartments could be maintained from 20° to 30° lower than the room temperature.

During the last twenty years, the household refrigerating machine has been under active development. It is only within the last five years, however, that machines have been manufactured in quantities and proven a commercial success.

Mechanical household refrigeration is having an important influence on refrigerator cabinet construction. It is necessary to have better constructed and insulated refrigerators

to operate satisfactorily, with the lower food compartment temperatures produced by the mechanical unit.

The cost of operation of the household machine is about the same as the cost of ice. When the interest of the investment and depreciation are considered they will usually cost more than ice. The increased sale of machines indicate that the advantages compensate for this difference in cost.

There are about 15,000,000 wired homes in the United States supplied with electric current. Less than 3 per cent of these have electrical refrigerating machines so there is a large potential market for this product. About 12,000,000 iced refrigerators are in use in the United States at the present time. There are about 9,000,000 wired homes in Europe.

The production of household refrigerating machines during recent years has been approximately as follows:

Previous to	1923	20,000
Year	1923	20,000
Year	1924	24,000
Year	1925	75,000
Year	1926	260,000
Estimate for year	1927	600.000 to 800,000

The gas fired absorption type household refrigerating machine is being rapidly developed at the present time. The cost of operation of this type machine can be considerably less than the cost of the equivalent amount of refrigeration with ice. There are about 17,000,000 gas meters in use in the United States.

It is predicted that, in the near future, the automatic household machine will compete with ice, even on a cost basis in homes having electric current or gas service.

CHAPTER I

REFRIGERATION UNITS AND THEORY

Heat Unit—A heat unit is an arbitrary standard or unit of measurement which expresses the capacity of a given body to absorb and retain heat energy under a given increase of its sensible heat. Water has a greater heat capacity than almost any other common substance and it has been used in framing the definition of a heat unit.

British Thermal Unit.—A British thermal unit (B.t.u.) is the quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit at or near its temperature of maximum density, 39.1° F. For practical work it may be considered as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Sensible Heat.—Sensible heat is the heat which goes to increase the temperature of a body without affecting its state, whether it be that of a solid, liquid or gas. Thus the addition of sensible heat to a body may be felt by the hand or be indicated by a thermometer.

Latent Heat.—Latent heat is the amount of heat that must be supplied to a body to change its state from a solid to a liquid, or from a liquid to change it to a gas. This heat separates the molecules of the substance and cannot be indicated by a thermometer since it produces no change in temperature. Every substance has a latent heat of fusion, required to convert it from a solid to a liquid, and another, a latent heat of vaporization required to convert it from a liquid to a gas or vapor. Experiments have shown that it requires 144 B.t.u.

to melt one pound of ice at 32° F. into one pound of water at 32° F.; thus we have 144 B.t.u. as the latent heat of fusion of ice.

If heat is applied to one pound of water at 212° F. the water will remain at this temperature under atmospheric pressure until all of it has been evaporated into steam at 212° F. This has been found to require 970.4 B.t.u.; therefore, the latent heat of vaporization of steam at atmospheric pressure is said to be 970.4 B.t.u.

Specific Heat.—The specific heat of a substance is the ratio of its heat capacity to that of water. One pound of water requires one B.t.u. to raise its temperature one degree F. One pound of cast iron requires only 0.13 B.t.u. Therefore, the specific heat of cast iron is 0.13. The specific heat of ice is 0.504; of air, 0.240, of anhydrous ammonia, 1.10. The specific heat of materials usually stored in a refrigerator averages about 0.80.

Refrigeration.—Refrigeration is a term used to represent the cold produced or rather the amount of heat removed. It is measured by the latent heat of fusion of ice. The capacity of a machine in tons of "ice melting" or "refrigeration" does not mean that the machine would make that amount of ice, but that the cold produced is equivalent to the melting of the weight of ice at 32° F. into water at the same temperature.

One ton of refrigeration is equal to 144x2,000 or 288,000 B.t.u. per 24 hours, or 12,000 Bt.u. per hour or 200 B.t.u. per minute.

Absolute Pressure. — Absolute pressure is the pressure reckoned from a complete vacuum. Gauges in common use indicate the pressure, in pounds per square inch, above atmospheric which is 14.7 at sea level; this reading is called gauge pressure. To convert gauge pressure to absolute pressure, 14.7 pounds, per square inch, must be added to the gauge reading.

Absolute Zero.—Absolute zero is the point at which molecules lose all motion; in other words, the temperature at which

there is an absence of all heat. This temperature has not been reached but is assumed to be 460 degrees below 0° F.

Mechanical Equivalent of Heat.—The mechanical equivalent of heat has been determined by accurate experiment. If the heat energy represented by one B.t.u. be changed into mechanical energy without loss, it would accomplish 778 foot-pounds of work. One hp. represents 42.416 B.t.u. per minute.

Refrigerating Machine Capacity Rating. — In December 1920, the A. S. R. E. and A. S. M. E. adopted a standard method for rating the capacity of any refrigerating machine which is concisely as follows:

"The capacity of any refrigerating machine shall be expressed in terms of 2,000 lbs. ice melting effect for 24 hours (288,000 B.t.u.) with 5° F. saturation temperature in the suction side and 86° F. saturation temperature at the discharge side."

Heat and Temperature. — Heat is a form of molecular energy. All bodies are composed of large numbers of extremely minute particles, known as molecules. These molecules have an attraction for each other, which is greater in solids than in liquids and greater in liquids than in gases. These molecules are in a state of continuous and irregular motion, the rate of which depends upon the temperature, being more rapid at higher temperatures. Absolute zero is supposed to represent the condition of matter where there is no kinetic energy of the molecules, and therefore no temperature. Absolute zero is —460° F., or —273° C.

Heat, being a form of energy, may be converted into electrical, chemical or mechanical energy. The two terms, heat and temperature, are frequently confused. Heat is a measure of quantity. Two pieces of iron may have the same temperature, however if one piece is larger than the other it will contain a larger quantity of heat. A cake of ice may contain more heat than a smaller quantity of boiling water. Heat is constantly passing from warmer objects to colder ones, just as water always tends to flow down hill. There is no natural process in which heat passes from a colder to a warmer object without the expenditure of outside work.

Temperature is a term used to denote the degree of hotness or coldness of a body and as explained above, it depends upon the amount of sensible heat contained in the body. Since our sensation of warmth and cold is not sufficiently accurate and trustworthy for technical purposes the physical change of expansion of a mercury, for example, accompanying its change in temperature has been agreed upon as a method of measuring temperature.

Theory of Refrigeration.—Refrigeration implies the reduction of the temperature of a body below the surrounding environment temperature. It further implies the maintaining of this temperature difference. This requires the constant extraction of heat from the space in which the temperature is already lower than the surrounding environment temperature.

Example.—The food compartment of a refrigerator is being maintained at a temperature of 45° F., and the room temperature is 70°. The refrigerator will continually absorb heat from the room. It is therefore necessary to "pump" this heat out of the refrigerator, as well as the heat supplied by placing relatively warm food or containers inside the refrigerator. To extract this heat from the 45° F. food compartment, it is necessary to have a still colder object such as a cake of ice, a brine tank, or cooling coil to continually absorb heat. The ice melts and the heat in the refrigerator is used to supply the latent heat necessary to change ice into water. With a brine tank in which are immersed the evaporator coils, the heat in the refrigerator is used to vaporize the liquid refrigerant in the coils, and a small amount to superheat the gaseous refrigerant, after being vaporized. The refrigerant is then compressed, and this heat passes into the condensing medium which is usually water or air.

Refrigeration Constants.—A number of the commonly used refrigeration constants are shown in Tables I to IX inclusive. Table I contains the interrelation of tons of refrigeration, pounds of refrigeration, and heat units (B.t.u.).

Table II gives the units of refrigeration, tons of refrigeration, and pounds of refrigeration expressed in B.t.u. per day, hour, minute and second. Due to the fact that the British

ton is 2,240 pounds, the corresponding British ton of refrigeration is therefore equal to 2,240X144=318,080 B.t.u. The corresponding American ton of refrigeration, 2,000X144=288,000 B.t.u.

Table III gives the tons of refrigeration required per ton of ice made when approximately 20 per cent is allowed for the losses occurring in the ice freezing process. Some of the common properties of ice are given in Table IV, while the weights of water per cubic foot and per gallon are given in Table V. Table VI contains some useful hp. equivalents. Some of the useful atmospheric pressure equivalents are given in Table VII. Some average weights of cork insulation are given in Table VIII. The heat transmission through one square foot of surface is found by dividing the total heat in B.t.u. transmitted per hour by the production of the mean temperature difference, and the heat transfer rate expressed in B.t.u. per square foot per degree of temperature difference per hour. Some of the fixed points in thermometry and other temperatures are given in Table IX.

TABLE I.—CONVERSION FACTORS

	Tons	Pounds	B.t.u.
Ton of Refrigeration	1	0.0005	0.000003507
Pound of Refrigeration	2,000	1	0.007014
B.t.u.	288,000	144	1

TABLE II.—TONS AND POUNDS OF REFRIGERATION

1 Ton Refrigeration =	288000	B.t.u. per day
1 Ton Refrigeration =	12000	B.t.u. per hour
1 Ton Refrigeration =	200	B.t.u. per minute
1 Ton Refrigeration =	3⅓	B.t.u. per second
1 Pound Refrigeration =	144	B.t.u. per day
1 Pound Refrigeration =	6	B.t.u. per hour
1 Pound Refrigeration =	0.1	B.t.u. per minute
1 Pound Refrigeration =	.001⅔	B.t.u. per second

TABLE III.—RELATION OF REFRIGERATION TONNAGE TO ICE MAKING

Temperature of Condensing Water degrees F.	Tons Refrigeration Per ton ice making
50	1.46
60	1.53
70	1.60
80	1.67
90	1.74

TABLE IV.—PROPERTIES OF ICE

Weight per cubic foot	57.5 pounds
Specific Heat	0.504 B.t.u.
Latent Heat	144 B.t.u.

TABLE V.—WEIGHT OF WATER

Weight per cubic foot	62.5 pounds
Weight per gallon	8.35 pounds

TABLE VI.—HORSEPOWER EQUIVALENTS

One mechanical horsepower = 33,000 foot pounds per minute
One mechanical horsepower = 2545. B.t.u. per hour
One mechanical horsepower = 746. watts

TABLE VII.—ATMOSPHERIC PRESSURE EQUIVALENTS

One Atmosphere = 14.67 pounds per sq. in.
One Atmosphere = 33.9 feet of water
One Atmosphere = 29.92 inches of mercury

TABLE VIII.—CORK INSULATION DATA

Weight per cubic foot, granulated = 6.5 pounds
Weight per cubic foot, regranulated = 8.0 pounds
Weight per cubic foot, corkboard = 12.0 pounds
B.t.u. heat leakage of one square foot corkboard

$$\text{per 24 hours} = \frac{6.5 \text{ x temp. difference}}{\text{Thickness in inches}}$$

TABLE IX.—FIXED POINTS IN THERMOMETRY

	Fehrenheit Degrees
Absolute zero (theoretical)	−460°
Mercury freezes	−38°
Water freezes	+32°
Household refrigerator (ideal temperature)	40° to 50°
Room temperature	68° to 70°
Pasteurizing milk	145°
Water boils	212°

CHAPTER II

ICE FOR REFRIGERATION PURPOSES

Historical Data.—The practice of cooling bodies below the temperature of the atmosphere by the use of ice, has been followed for centuries. In the earlier times, the ice used for refrigeration purposes was natural ice, which formed on the rivers, lakes and ponds, during the cold winter months. The ice, after being harvested in the winter, was stored in caves in the ground, so that perishable foods could be preserved during the hot summer months. Coming up to modern times, we find, in the last half of the nineteenth century, due to improved methods of storing, harvesting, and distribution, that the use of natural ice for refrigeration purposes assumed a large proportion in the United States. Later, practically within the time of the present generation, means were devised whereby ice for refrigeration purposes could be procured by mechanical means in commercial quantities. Still later, within the last decade, attention has been directed to ways and means of producing refrigeration in the home by mechanical means directly.

At present this subject is receiving the attention of many inventors, engineers, manufacturers, and others. New and improved devices and processes are being developed constantly.

The National Association of Ice Industries has recently published a bulletin, entitled "The Romance of Ice," which contains an interesting review of the historical data on this subject. The following has been extracted from this bulletin:

THE ROMANCE OF ICE

Prologue.—Every product, every industry, every modern development has its "story." Perhaps the pages have not been turned back to that he who runs may read and be interested, but the story is there. Some of our greatest untold romances concern those taken-for-granted commodities which the public sees, uses, enjoys, without giving a thought to their interesting origin or the struggles of men in their development.

For example, ice is a necessity without which the public would really suffer. True the blasts of winter turn the waters of river, lake, and pond into ice; one long puff from Boreas' cheeks provides thousands of tons of ice each year, but twenty-six million American families cannot be supplied by Nature's manufactory alone.

Let's turn back the pages of history for a moment and see what happened in the world of yesterday to make ice now as readily accessible as coal or wood. These pages reveal real romance.

History.—The early Greek poet, Simonides, while at a banquet, observed that the liquor served to the other guests was cooled by snow. Whereupon he expressed his dissatisfaction in the following ode:

> "The cloak with which fierce Boreas clothed the brow
> Of high Olympus, pierced ill-clothed man
> While in its native Thrace; 'tis gentler now,
> Caught by the breeze of the Pierian plain.
> Let it be mine: for no one will commend
> The man who gives hot water to a friend."

History's pages also show that the ancient Egyptians knew the secret of cooling by evaporation, as practiced by the native of India today—filling with water shallow trays of porous material placed on beds of straw, and leaving them exposed to the night winds, with the result that dawn finds a thin film of ice formed on the surface.

On a very early page we find that the Emperor Nero had slaves bring snow down from the mountains to cool his wines. Alexander the Great had trenches dug for storing snow. Hundreds of kegs of wine were cooled there, with the result that his phalanxes entering battle the next day didn't care much what became of them, just so it was a good battle.

Marco Polo, the great Italian navigator, brought recipes for water and milk ices from Japan and China in the thirteenth century.

When Catherine d'Medici left Florence, Italy, to go to France, in the sixteenth century, she took with her the best of the chefs to make sure that she would be supplied with frozen creams and ices every day.

Sir Walter Scott told how Saladin, leader of the Mohammedan armies, sent a frozen sherbet to Richard the Lion Hearted, much to the amazement of that doughty monarch.

During the seventeenth century the French government made an unsuccessful attempt at government ownership when it licensed the business of farming snow and ice. The farmers who received government favor thereupon raised prices with such studious regularity that the people refused to buy and the Government was forced to relinquish its control of this commodity. Immediately thereafter supply and demand got into its stride and the business settled back into sanity.

As Lord Bacon commented in his Sylva Sylvarum:

> "Heat and cold are Nature's two hands whereby she chiefly worketh, and heat we have in readiness in respect of the fire, but for cold we must stay till it cometh or seek it in deep caves or mountains, and when all is done, we cannot obtain it in any great degree, for furnaces of fire are far hotter than a summer's sun, but vaults and hills are not much colder than a winter's frost."

Bacon knew what a useful thing it would be if man could have the same command of cold as of heat. Scientist that he was, he undertook experiments into its possibilities. This led to unfortunate results, as he caught his death of cold by alighting from his carriage one winter day and stuffing snow into a chicken to see if it would keep.

The Italians, Spaniards, and Frenchmen have always been devotees of better living, and history is filled with interesting side lights on their uses of snow and natural ice.

Then we have the picture of the early fishmonger in England selling ice from his wagon, a practice which is continued to the present day.

The first record of American delivery of ice to the home is in 1802. The first commercial shipment of natural ice from America was exported from Boston by Frederick Tudor in 1805 when a shipload was sent to Martinique in the West Indies to help stay the ravages of yellow fever.

During this time all of the ice used was produced by Nature.

Natural and Manufactured Ice.—One of the most interesting phenomena of Nature is the formation of ice. We all know that cold is the absence of heat and that the freezing point of water is 32° F. When the air above a pond, lake, or river is below 32° F., the top layer of water is cooled and will sink because it is heavier than the warmer layers underneath. This continues until all the water is cooled to 39.1° F., at which point water reaches its greatest density. The top layer will then be cooled still further but remains on top and eventually will be reduced to the freezing point and ice will form.

If the water undearneath the ice is not in motion, opaque ice will form. On moving bodies of water, as rivers and large lakes, clear ice forms. This is because each drop of water in freezing sets free the air it contains. The bubbles of air adhere to the surface of the newly frozen ice crystal. As more ice encloses the bubbles, the product becomes opaque. But where the water is in motion, the bubble is washed off the surface of the newly formed ice crystal and thus the ice forms, clear and hard.

But how about the actual manufacture of ice?

As Edwin F. Slosson of the Science Service, Washington, D. C., explains in his article, "Science Remaking Everyday Life:"

> "The chronicle of the century of effort to approach the farthest north of temperature, absolute zero, is as fascinating as the contemporary struggle to reach the geographic pole and unlike the latter has proved profitable at every stage. When Fahrenheit in 1724 stuck his mercury thermometer into a mixture of salt and snow, he thought he had reached the lowest point possible and boldly scratched zero on the tube. But it was not long before scientists began to climb down the minus steps. In 1769 a Russian professor, taking advantage of a cold spell, froze mercury itself in a mixture of snow and nitric acid."

A hundred years ago, Faraday, working in the Royal Institution of London, succeeded in condensing ammonia gas to a liquid by applying pressure and then cooling it. When the pressure was removed, the liquid of course boiled off rapidly as a gas, absorbing heat in doing so. Any liquid absorbs heat when it turns into a gas.

This discovery proved of the greatest importance, both practically and theoretically. A solution of ammonia and water was used by Carre in 1858 in his ice making machine. The first Carre machine to reach the United States was shipped through the blockade of New Orleans in 1863.

In 1755 Dr. William Cullen invented the first machine which produced ice by purely mechanical means, his achievement being followed by those of Vallance of France (1824) and Jacob Perkins, an American then residing in England, who is given credit for the forerunner of the modern compression apparatus, his model being patented in England in 1834, with ether as the refrigerant employed. Other early workers in this field of science were Prof. A. C. Twining, of New Haven, Connecticut, and Dr. John Gorrie, of Appalachicola, Florida.

In the rotunda of the capitol at Washington, where each of the states has set statues of its most distinguished citizens, Florida has chosen this same Dr. Gorrie instead of any of its pioneer politicians or military geniuses. Too many men of various countries have con-

tributed to the gradual development of mechanical refrigeration for any one person to be entitled to exclusive credit for the invention, but Dr. Gorrie certainly deserves this place in our National Hall of Fame for the service rendered to the country when he took out the first American patent in 1850 for a practical process of manufacturing ice.

In the years of 1873-75 the first successful ammonia compression machines were introduced by C. P. G. Linde of Germany, and David Boyle of the United States. From 1875 to 1890 many new forms of apparatus were produced and certain improvements were made.

Until the year 1890 the practical utilization of the art of ice making and refrigeration had seemed to come to a standstill. But there occurred in the year 1890 an incident that awakened the general public to the possibilities of the use of mechanical refrigeration. This incident was the greatest shortage in the crop of natural ice that has ever occurred in the United States. To this unusual shortage may be accredited the impetus that started the rapid development and utilization of mechanical refrigeration. Since 1890 the ice making and refrigerating industry has grown by leaps and bounds.

Thanks to the manufacturers of the refrigerating machine, ice can be had at any time and anywhere that power can be obtained. The ice machines give us ice in any quantity at any time.

Manufactured ice is made in cans holding 300 to 400 pounds. The can is filled with pure water and is let down into a tank which is filled with brine. The brine is made of sufficient density to permit its freezing point to fall to zero Fahrenheit or below. The cans are arranged in regular order, in rows; between these rows of cans are continuous coils of closed pipe through which passes the ammonia, it being the most commonly used refrigerant. The ammonia starts out as a liquid and expands, turning into a vapor and finally into a gas as it absorbs heat from the brine which surrounds the coils

As the ammonia circulates through the pipes in the brine tank, it absorbs the heat from the brine and lowers its temperature to a point below the freezing point of water. As heat always travels from the higher to the lower temperature, the brine, in turn, absorbs heat from the water in the cans. When the temperature reaches a point low enough, the water begins to freeze and ice forms on the inside of the cans. As the freezing continues, the ice thickens until it finally closes to the center of the can and is a solid block. As the ice forms, any foreign matter in the water is forced to the center of the block. In order to manufacture clear ice, it must be made from distilled water or from "raw water," which is low in mineral content. The water must also be kept in motion just as Nature keeps the river water moving. By so doing, the particles of air and gases are liberated and

come to the top, thus allowing clear ice to be frozen. This is accomplished by conducting a stream of cold air into the can which keeps the water in motion. Frequently, in order to get a cake that is clear and clean all the way through, avoiding what is called a "core," the water is drawn from the center of the can before it is completely frozen and this cavity is refilled with distilled water.

What Ice Can Do.—When ice melts, it absorbs heat. Each pound changing from solid ice to liquid water absorbs as much heat as would be required to raise the temperature of one pound of water 144 degrees Fahrenheit. Indeed, the heat absorbing capacity of ice is so great that it has been made the standard of comparison and the units in which we measure this power are called British thermal units.

Ice is greedy to absorb heat. Therefore, if it is to do specific work, it must be protected from those warm objects which we do not desire cooled. For instance, in our home refrigerators ice is placed inside of what we term insulated walls.

A material which does not allow heat to pass through it is called an "insulator." To keep the ice from melting too rapidly, we build into the walls of the container some insulator which keeps away the atmospheric heat. The articles to be preserved for cooking or to be kept cold are put into the insulated space with the ice. Then the ice can absorb their heat, thereby cooling them, but turning into water in doing so. This is the principle of all ice refrigerators.

The better the insulation, the less heat can get into the refrigerator or ice box, and therefore, the less the ice meltage due to heat leakage. The warmer the articles put into the box, the more ice they will melt before they reach the same temperature as the ice box itself.

The temperature of ice is 32° F. If we had a perfect insulator—one which would not allow any heat from outside to go through the refrigerator walls, the temperature of the inside of the refrigerator would be 32° F. also. However, all insulators allow some heat to pass; the best ones permit little, while the poor ones let much heat pass through. The poorer the insulation in the refrigerator, the higher will be its temperature and the more ice will be melted when the air outside is warm.

The question of proper air circulation in a refrigerator is one of vital importance. The heat enters the refrigerator in two ways; some through the walls of the box and some with the food to be cooled. The warm air travels to the ice, is cooled, drops down to the section directly under the ice and thence over the food, absorbing heat, moisture, and odors. The warmed air, being lighter, rises through the food chamber and again reaches the ice. Here the air is cooled, drops moisture because of its lowered temperature, and whatever odors may have been absorbed during its passage over the food are dissolved in

the film of water on the surface of the melting ice and pass off in the meltage. Then the cooled, dried, and cleaned air is ready to make another trip through the food compartment.

The intelligent housewife utilizes these facts to the advantage of her family and her pocketbook. She sees that the ice compartment of the refrigerator is ready to receive the ice when the ice man brings it. Every minute it stays outside the insulated space it is absorbing heat from the air and melting.

Refrigeration is the ideal preservative and the housewife who really wants to economize on both food and ice keeps her refrigerator well filled at all times. This is a simple matter of household efficiency. When the ice gets low in the refrigerator, the walls naturally grow warm and just that much more ice is required to bring the temperature down again to a safe point where the constant circulation of cold air across the top of the ice, down its sides, down the side of the small food compartment, across the floor of the refrigerator, up through the food compartment and over the ice again purifies, and preserves through every inch of its journey.

Ice in Daily Living.—In a multitude of ways ice has entered into the daily life of the American people. It tinkles in the glass of water with which the master of the house quenches his thirst; it furnishes soft, clean water to shampoo milady's hair; and a small piece rubbed on her satiny cheek brings the blush of youth. In the laboratory the scientist depends upon it to chill his mixtures, and, in the hospital the physician prescribes it to cure and to comfort. But most important of all is the use of ice to maintain freshness, wholesomeness, and high quality in foods, and, directly or indirectly, most of the ice produced is utilized for this purpose.

We are apt to think that the piece of ice in the home refrigerator is the ice which is doing the work of food preservation, which is true. But far behind the household refrigerator there is a long refrigerated channel through which foods travel from producer to consumer. For example, each refrigerator car holds from three to five tons of ice. We have a fleet of about 150,000 such cars. One filling of ice is seldom enough to protect the lading for the entire haul and, for long hauls such as from the Pacific to the Atlantic coast as much as ten tons of ice per car may be required. This means that millions of tons of ice each year are used to protect our foods while in transit.

And then, just think of the hundreds of thousands of butcher boxes, large and small, in which ice is the refrigerant.

How insignificant would apear the few ices and sherbets made by Catherine d'Medici's chef when compared with the great ice cream industry of this country. Though much of the ice cream manufactured in this country is frozen by mechanical means, yet millions of pounds

of ice are required each year in the packing and handling of the product. Over 300,000,000 gallons of ice cream are manufactured each year, to say nothing of the large quantities made in homes where ice must be used in the freezing process.

Of all the foodstuffs kept from spoiling by means of ice none is of such importance as milk. Neither is there any food which depends to such an extent upon ice to maintain its purity. From the cooling of the milk with ice on the farm to the cracked ice in the container for the bottles on the milkman's wagon, milk is never for one moment from the cow to the consumer unaccompanied by its guardian and caretaker—ICE.

What the Ice Industry Is Doing.—More than 6,000 factories supply America today with over 42,000,000 tons of ice each year. In addition to this the harvesters of natural ice supply about 15,000,000 tons per annum. It is the duty of the industry to see that the American public is supplied with enough ice for all needs the year 'round. To fulfill this responsibility requires a large investment in money and men as well as sound business policy to serve the public economically and produce that reasonable profit which must accrue to every successful industry. For example, the city of New York uses each year 3,750,000 tons of ice. That the supply may not fail when warm weather comes and the demand increases manyfold, ice is manufactured and stored for months or until there is an accumulation of 200,000 tons which is not considered excessive as a margin of safety for the consumer. This is in addition to an average daily capacity for production in the ice plants of greater New York City of 23,000 to 24,000 tons. Similar precautions are taken the country over.

Not only the large city but the small town and the country side must find ice available should the need or the desire arise. Accordingly, we find small ice plants dotting the country from Canada to Mexico and from Coast to Coast. Longer and longer are the delivery routes and more and more frequent the supply stations. Into the depths of the Grand Canyon where it is eternally summer, ice is brought by burro back. On the banks of northern waters great houses store Nature's product that even in the North food may be preserved in warm weather.

To give an idea of the amount of equipment necessary and the volume of business carried on, it is interesting to note that manufacturers of ice in large cities such as New York may have as many as five hundred trucks and wagons in service, employ as many as one thousand men and manufacture as much as one million and a half tons of ice per year.

Such is the story of ice and the part it has played as the centuries have rolled on and man has become more and more the master

of the elements about him. That he now holds the key which regulates temperature, has been a development successful only after toil and struggle.

But the benefits are available to all of us.

Properties of Ice.—Most substances on being cooled become denser, changing from vapor to liquid and then to solid form, each more compact than the preceding form. Water is an exception to this general law. Water upon being cooled behaves normally and becomes denser until cooled at 39°. Further cooling expands the water until 32° is reached, when it freezes. Ice forms with an expansion. If this were not so, lakes would freeze from the bottom up. One can skate on ice because the pressure melts the ice, making a thin film of water. It requires energy to change from a solid to a liquid as this is a property common to crystalline substances.

Ice freezes in crystals, hexagonal in shape. When ice is frozen in the ordinary can method, these prisms have the hexagonal side on the surface of the cake of ice. If there is no agitation of the water during the freezing process, these prisms will continue in straight surfaces from the outside of the cake to the center. When there is agitation of the water during the freezing, the crystals break and pile up, forming irregular lines and surfaces. This is the reason a sun test will melt a 300 lb. cake of ice frozen without agitation, from four to five hours sooner than it will melt a similar cake of ice frozen with water agitation. The light, air, and heat enter the cake frozen without agitation with much less resistance.

A cake of ice frozen with agitation has about one per cent greater density than a cake of the same size frozen without agitation.

One cubic foot of ice at 32° F. weighs 57.50 pounds.

One pound of ice at 32° F. has a volume of 0.0174 cubic feet or 30.067 cubic inches. The relative volume of ice to water at 32° F. is 1.0855. The specific gravity of ice is 0.922. The specific heat of ice is 0.504.

Quantity of Ice Required for a Dairy Farm.—The United States Department of Agriculture in Farmers' Bulletin No.

1078 gives the following information in reference to the quantity of ice required for a dairy farm:

The quantity of ice needed for a dairy farm depends on its location, number of cows milked, and methods of handling the product. In the Northern States, it has been found that with a moderately good ice house, where the shrinkage from melting is not more than 30 per cent, half a ton of ice per cow is sufficient to cool the cream and hold it at a low temperature for delivery two or three times a week. It must be understood, however, that suitable cooling tanks are necessary under this estimate. The half-ton-per-cow estimate for ice to be stored allows for a reasonable waste and also for ordinary household use. If whole milk is to be cooled the quantity of ice stored must be increased to one and a half tons per cow in the North and two tons per cow in the South. To meet the needs of the average family on a general farm, it will be necessary to store about five tons.

Cost of Harvesting Ice.—The United States Department of Agriculture in Farmers' Bulletin No. 1078 gives the following data on the cost per ton for harvesting ice:

The cost of harvesting ice also varies with local conditions. It is impossible, therefore, to give an estimated cost that will cover all cases. The ice-harvesting season fortunately comes at a time when there is the least work on the farm for men and teams, and consequently the actual money cost is usually not very great. Investigations have indicated that counting the full value of the men's time, the average cost of cutting ice is about 27 cents a ton. Add to this the cost of packing and hauling, and the average cost of a ton of ice is about $1.50, when the ice house is near the source of supply. If the ice house is at a considerable distance the cost of hauling, of course, is increased, and the total cost of storing ice in some instances has amounted to $3.00 or more a ton.

Refrigeration Required for Making Ice.—The refrigeration required to make a pound of ice may be calculated as follows, when the initial temperature of the water is 75° F.:

To cool water (75° F.—32° F.)............	43 B.t.u.
To freeze water (latent heat=144)........	144 B.t.u.
To cool ice from 32° F. to 18° F. (0.504x14)	7 B.t.u.
Total	194 B.t.u.

These quantities are shown graphically by Fig I. An additional amount of refrigeration, equivalent to from 15 per cent to 20 per cent of the foregoing, must be allowed to cover the unavoidable losses during the freezing of the ice. The foregoing methods, together with an allowance of approximately 20 per cent for losses, were used for the calculation of the data given in Table III of Chapter 1.

Size of Ice Cans.—Recent survey of the different sizes of ice cans indicated there were being manufactured at present about fifty different sizes. Of course, a great portion of the ice manufactured in the United States is frozen in 300 lb. and 400 lb. cans. Table X gives the sizes of the so-called standard ice cans. These particular sizes are used in a great majority of the plants.

TABLE X.—STANDARD SIZES OF ICE CANS

Size of cake, in pounds	Size of top, inches	Size of bottom, inches	Inside depth, inches	Outside depth, inches	Size of band, inches
50	8x 8	7½x7½	31	32	¼x1½
100	8x16	7¼x15¼	31	32	¼x1½
200	11½x22½	10½x21½	31	32	¼x2
300	11½x22½	10½x21½	44	45	¼x2
400	11½x22½	10½x21½	57	58	¼x2

Cutting of Ice Into Blocks.—The cutting of ice into blocks suitable for household refrigerators should be given special attention. The 25 pound unit system of cuts is in general use. The larger or 100 pound blocks are cut from the ends of the cake and the 50 pounds cuts are made by splitting the middle 100 pounds blocks. The 300 and 400 pound ice cakes usually have from five to ten per cent overweight to allow for loss in melting during storage and delivery.

Ice scoring machines are being used by the more progressive manufacturers. Some of the advantages of the ice scoring machines are: Insures customer of full weight, saves time in delivery, and gives blocks of suitable dimensions for standard ice compartment. The ice scoring machine has a series of saws which score the two largest faces at the same time. The scoring for a 300 pound block requires one horizontal and five vertical cuts.

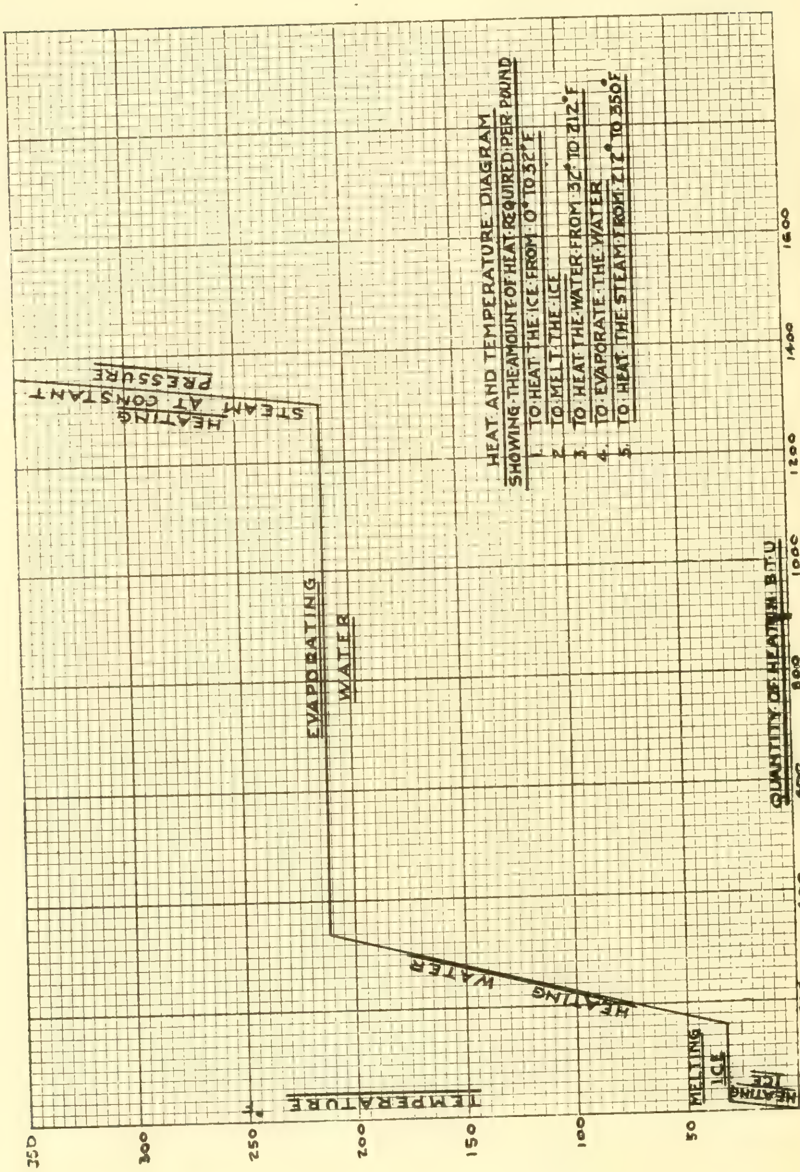

FIG. 1.—HEAT TEMPERATURE DIAGRAM FOR ICE, WATER AND STEAM.

Water.—Some of the dissolved solids found in ordinary tap water are as follows:

Silica,	Sulphate of soda,
Carbonate of iron,	Chloride of soda,
Alumina,	Carbonate of soda,
Carbonate of lime,	Chloride of lime,
Sulphate of lime,	Chloride of magnesia.
Carbonate of magnesia,	

The first six of this list are scale forming solids.

CHAPTER III

REFRIGERANTS

General Requisites.—The most desirable refrigerant should possess the following properties:

1. A high latent heat as well as a high ratio of the latent heat to the specific heat of the liquid, in order to produce a large refrigerating effect per cycle of operation.

2. A boiling point at ordinary atmospheric pressure low enough to obtain the temperature desired.

3. A condensing temperature at a relatively low pressure.

4. A low specific volume of vapor.

5. A high critical temperature.

6. A low ratio of compression.

7. A non-corrosive action on metals.

8. A chemical composition which is stable under working conditions and inert on lubricants and gaskets.

9. A non-inflammable and non-explosive nature even when mixed with air.

10. An inoffensive odor, non-injurious to health.

11. A behavior whereby its presence in small quantities may be visibly detected by a simple test.

12. A low cost of production for a product of necessary chemical purity for commercial use.

13. No affinity for constituents of the atmosphere whereby leaks might form gases or acids effecting the normal operation of the system.

14. A non-corrosive action on desirable bearing materials.

Refrigerants for Household Systems.—There are approximately 500,000 household refrigerating machines in operation

in the United States. Sulphur dioxide is the refrigerant used in more than 75 per cent of these systems. Some of the other mediums employed are: methyl chloride, ethyl chloride, butane, isobutane, ammonia, propane, carbon dioxide, ether, air and water vapor.

Amonia is used in more than 90 per cent of the larger or commercial refrigerating plants.

Carbon dioxide is now used extensively for refrigerating systems in boats where formerly ethyl chloride and air machines were favored. Carbon dioxide and air machines are considered safer than machines with other refrigerants, in case of accident or fire. Carbon dioxide is used rather extensively in Europe for small household machines and its use in cooling theatres and public buildings is increasing in the United States.

Ether has some use in small hand operated machines which are manufactured in Europe and sold in the tropics.

Nitrous oxide has a limited use in the chemical industries when very low temperatures are desired.

Pressure of Condensation. — The condensing pressure should be comparatively low. Assuming 86° F. as the condensing temperature, the following pressures are obtained with the refrigerants in common use:

Ether	2.4	Lbs. Gauge
Ethyl Chloride	12.40	Lbs. Gauge
Sulphur Dioxide	51.75	Lbs. Gauge
Methyl Chloride	80.83	Lbs. Gauge
Propane	143.0	Lbs. Gauge
Ammonia	154.5	Lbs. Gauge
Ethane	666.0	Lbs. Gauge
Nitrous Oxide	915.3	Lbs. Gauge
Carbon Dioxide	1024.3	Lbs. Gauge

The high condensing pressure reached with carbon dioxide and even ammonia, necessitates very strong and well made apparatus. The carbon dioxide machines in use today are water cooled. The ammonia machines are also water cooled. Air cooled ammonia machines have been built but have not been used commercially. Sulphur dioxide machines have been placed on the market, both as water cooled and air cooled. The air cooled operate at a condensing pressure of 10 to 20 pounds higher than the water cooled type. Air cooling lowers

the efficiency, but increases the simplicity of the refrigerating system. A study of the development of household machines indicates that it is very desirable to use air cooled condensers to obtain simplicity, lower initial cost, and lower installation costs. Air cooled condensers are now used almost universally in household machines of the compression type.

It has not proven practical to use air cooling for refrigerants operating at a condensing pressure of more than 150 lbs. gauge. It is usually necessary to centralize the piping with refrigerants having a condensing pressure of over 150 lbs. gauge and distribute the refrigeration by means of a brine system.

Pressure of Vaporization. — The following evaporating pressures are obtained with the refrigerants in common use at 5° F., evaporating temperature.

Ether	—13.19 Lbs. Gauge
Ethyl Chloride	—10.05 Lbs. Gauge
Sulphur Dioxide	—2.88 Lbs. Gauge
Methyl Chloride	6.19 Lbs. Gauge
Ammonia	19.57 Lbs. Gauge
Propane	30.5 Lbs. Gauge
Ethane	221.0 Lbs Gauge
Nitrous Oxide	318.3 Lbs. Gauge
Carbon Dioxide	319.7 Lbs. Gauge

The evaporating pressure has an important influence on the stuffing box. The packing is usually made to take up wear automatically. It is advantageous to have nearly the same pressure on both sides of the packing.

Sulphur dioxide operates at an evaporating pressure very close to atmospheric pressure, thus favoring this condition better than any of the other refrigerants in common use.

With a refrigerant such as ethyl chloride, which normally operates with a partial vacuum on the evaporator, it is very difficult to locate a leak as air could enter the system unnoticed, and would greatly reduce the efficiency of the apparatus.

Some household machines have all moving parts entirely enclosed, thus eliminating this packing gland difficulty. The compressors so far designed with a method of eliminating the packing gland include the design features which have not as yet proven practical in large quantity production. Other

machines have an oil reservoir on both sides of the stuffing box, so that any small leak would be of oil either into or out of the compressor crank case. This would depend upon the pressure inside the crank case being above or below atmospheric pressure.

Latent Heat of Vaporization.—The latent heat of vaporization should be carefully considered in selecting a refrigerant for a household machine. One of the most difficult problems is the expansion valve, float valve, or liquid restriction device, which controls the rate of flow of liquid from the condensing to the evaporating side of the system. With a high latent heat of vaporization, this problem is more difficult, as it is then necessary to control through a more sensitive valve (the amount of liquid circulating per minute being less). In making this comparison it is also necessary to consider the condensing and evaporating pressures. These determine the pressure differential trying to force the liquid through the expansion valve.

This problem is more difficult with ammonia than with sulphur dioxide, as it is necessary to circulate three to four times more refrigerant in the sulphur dioxide system, because of its lower latent heat of vaporization, while the pressure differential between the condensing and evaporating sides are less than in an ammonia system. On larger refrigerating systems, the liquid control problem is less difficult; therefore, a refrigerant with a high latent heat of vaporization is preferred.

Carbon dioxide has a very low latent heat of vaporization, about half that of sulphur dioxide. However, the pressure differential is so great as to more than offset the advantage of having a lower latent heat.

The latent heat of vaporization of the household refrigerants in common use at 5° F. is:

Carbon Dioxide	115.30	B.t.u.	per	Lb.
Nitrous Oxide	121.4	B.t.u.	per	Lb.
Sulphur Dioxide	169.38	B.t.u.	per	Lb.
Propane	169.5	B.t.u.	per	Lb.
Ethane	176.0	B.t.u.	per	Lb.
Ethyl Chloride	177.0	B.t.u.	per	Lb.
Methyl Chloride	178.5	B.t.u.	per	Lb.
Ammonia	565.0	B.t.u.	per	Lb.

Corrosion of Metals.—An important factor in choosing a refrigerant is the corrosive action on metals. Sulphur dioxide has no corrosive action on iron or steel, unless there is water present. Water and sulphur dioxide combine chemically as follows:

$$\begin{array}{cccc} H_2O & \text{plus} & SO_2 & = H_2SO_3 \\ \text{Water} & \text{plus} & \text{sulphur dioxide} & = \text{Sulphurous acid} \end{array}$$

Sulphurous acid is formed, which will attack iron This condition sometimes occurs, resulting in a so-called "frozen" compressor. The pistons will "freeze" to the cylinders so tightly that it is necessary to take the compressor apart and remove such material before operating again.

Sulphur dioxide has no chemical or corrosive action on copper or copper alloys, thus permitting the use of copper tubes for the condensing and cooling elements. This is an advantage, as the thermal conductivity of copper is seven or eight times greater than that of steel or iron. Copper or copper alloys cannot be used with ammonia when there is water present. Copper can be used with anhydrous ammonia. Copper lines are used on some absorption machines using a solid absorbent and charged with anhydrous ammonia.

Methyl chloride, ethyl chloride, butane, and carbon dioxide have no chemical or corrosive action on copper, copper alloys, iron or steel; therefore, these refrigerants may be used with any of these metals.

Testing for Gas Leaks.—Sulphur dioxide is one of the two refrigerants, ammonia being the other, with which it is possible to find leaks by means of a visible method called the "smoke" test.

The smoke test consists of placing aqua ammonia near the sulphur dioxide leak. A chemical reaction occurs and dense white smoke apparently issues from the opening.

$$SO_2 + H_2O = H_2SO_3$$
$$2NH_4OH\ H_2SO_3 = (NH_4)_2SO_3 + 2H_2O$$

$(NH_4)_2SO_3$ is a white solid ammonium sulphite. A burning sulphur stick is used in testing for an ammonia leak.

A small alcohol flame is sometimes used in testing for an appreciable leak of methyl chloride. The flame is passed near the connections to be tested. A leak of methyl chloride will

impart a green color to the nearly colorless alcohol flame. There is no danger of igniting an explosive mixture of methyl chloride and air in making this test. It is necessary to have at least 10 per cent and not more than 15 per cent of methyl chloride present by volume to form an explosive mixture with air. It is impossible to remain in a room for more than a minute or two with this concentration present because of the physiological effect upon breathing.

Another method used to find leaks of methyl chloride is to use a small electrically heated wire. The wire is heated to a dull red temperature. While the wire is being applied, the fumes of ammonia are brought near. If methyl chloride is present a fume will result, due to the decomposition of the methyl chloride to hydrochloric acid and carbon and the reconstruction of the hydrochloric acid set free with the ammonia.

Comparisons of Refrigerants for Household Machines.—From foregoing considerations it will be observed that the operating pressures, latent heat of evaporization, facility for testing for gas leakage, inflammability, corrosive action on

TABLE XI.—REFRIGERANTS FOR HOUSEHOLD MACHINES

Relative Advantage for Use in Household Machines. Listed in order of preference under each heading.

Operating Pressures	Latent Heat of Vaporization	Testing for Gas Leaks	Inflammability	Corosive Action on Metals	Danger of Breathing Small Concentration of Gas in Air	Lubrication
Sulphur dioxide	Carbon dioxide	Ammonia	Carbon dioxide	Methyl chloride	Carbon dioxide	Sulphur dioxide
Methyl chloride	Sulphur dioxide	Sulphur dioxide	Sulphur dioxide	Ethyl chloride	Ethyl chloride	Ammonia
Ammonia	Ethyl chloride	Methyl chloride	Ammonia	Ether	Methyl chloride	Methyl chloride
Ethyl chloride	Methyl chloride	Ether	Methyl chloride	Carbon dioxide	Ether	Ether
Ether	Ether	Ethyl chloride	Ethyl chloride	Sulphur dioxide	Ammonia	Carbon dioxide
Carbon dioxide	Ammonia	Carbon dioxide	Ether	Ammonia	Sulphur dioxide	Ethyl chloride

metals, danger of breathing, and lubrication, are the principle factors to be considered in the selection of a suitable refrigerant for household refrigerating machines. With these factors

in mind, the author has prepared Table XI, to show the relative advantages of various refrigerants in household machines. These are listed in order of preference, under each of the headings for sulphur dioxide, ethyl chloride, ammonia, methyl chloride, ether, and carbon dioxide.

Characteristics Influencing Selections.—The following are some of the general characteristics influencing the selection of refrigerants:

1. The condensing pressure should be reasonably low at tap water or atmospheric air temperatures, depending upon the cooling medium used. The evaporating pressure necessary to freeze ice in a reasonable length of time should be close to atmospheric pressure, preferably above, to prevent gas leaks when a stuffing box is used. The ratio of compression between the condensing pressure and pressure of vaporization should be small in order to facilitate the functioning of the expansion valve.

2. A low latent heat of vaporization is preferred so that a larger amount of liquid refrigerant circulates to do the same amount of cooling. This makes the expansion valve or liquid control restriction less sensitive and permits the valve to leak more without affecting normal operation.

3. A refrigerant having a visible or "smoke" test for leaks is preferable as it is then not necessary to test every joint with oil or soap water. It is extremely difficult to find leaks if a refrigerant operates at a pressure less than atmospheric as air can leak into the apparatus affecting normal operation before the leak is detected.

4. A non-inflammable refrigerant is preferred in order to prevent danger in case of a gas leak in the refrigerating system in a home and also to prevent danger in case of fire.

5. A refrigerant is favored which does not have a corrosive or chemical action on metals. It is advantageous to be able to use copper and copper alloys for heat interchange apparatus on account of the higher rate of heat conductivity. Some refrigerants have a corrosive effect on metals when water or gases from the atmosphere are allowed to enter the refrigerating system.

6. Preference is given to the different refrigerants in accordance with the percentage of gas, which, when mixed with air, will not give discomfort when breathed for a considerable length of time.

7. It is preferable to use oil as a lubricant. It is desirable to eliminate the oil trap. The lubricant problem is more difficult when larger volumes of gas must be compressed, often necessitating a rotary compressor.

Amount of Refrigerant to Be Evaporated.—The relative amount of the liquid refrigerant to be evaporated to produce refrigeration at a given rate depends upon the relative latent heat of vaporization and sensible heat of the respective refrigerant. Generally, those refrigerants which have high latent heat of evaporization require a small amount of liquid to be evaporated to produce a given refrigerating effect. This is illustrated by ammonia, which has a fairly large latent heat of evaporization. On the other hand, certain refrigerants have

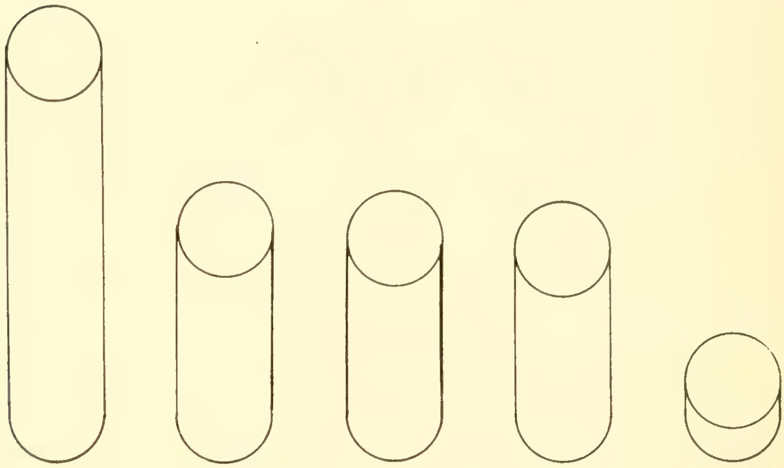

FIG. 2—AMOUNT OF LIQUID REFRIGERANT TO BE EVAPORATED

low latent heats of evaporization, in which case, the sensible heat of the liquid corresponds to a large proportion of the available latent heat of evaporization. By sensible heat of liquid is meant the heat required to cool the liquid refrigerant from the temperature at the exit from the condenser, or at a point just before the expansion valve to the temperature existing in the evaporator. Carbon dioxide is one of the representative refrigerants which has a fairly small latent heat of evaporization. Fig. 2 shows graphically the amount of refrigerant which must be evaporated per minute to produce one pound of ice melting effect per 24 hours for carbon dioxide, ethyl chloride, methyl chloride, sulphur dioxide, and ammonia.

Use of Refrigerants in the United States.—The various types of refrigerating plants using different refrigerants in the United States may be classified into large commercial plants, small commercial plants, marine installations, and household refrigerating machines. In a large commercial plant, it will be found that ammonia is used extensively; in small commercial plants ammonia is used extensively also; in marine installations, carbon dioxide is used extensively, and in the household machines, sulphur dioxide is used extensively. Table XII shows the use of the different refrigerants in the United States at present.

TABLE XII.—USE OF REFRIGERANTS IN UNITED STATES

Table Showing Present Usage in U. S. for Various Types of Refrigerating Plants.

	Large Commercial Plants	Small Commercial Plants	Marine Installations	Household Machines
Ammonia (Compression)	Extensive	Extensive	Limited	Very Limited
Sulphur Dioxide	None	None	Very Limited	Extensive
Methyl Chloride	None	None	Very Limited	Limited
Ethyl Chloride .	None	None	Very Limited	Limited
Carbon Dioxide .	Limited	Limited	Extensive	Very Limited
Air	None	None	Very Limited	Very Limited
Ammonia (Absorption) .	Limited	Limited	None	Limited
Isobutane	None	None	None	Limited

Comparative Cylinder Displacements.—On account of the fact that the different refrigerants have different latent heats of evaporation and sensible heats of liquid, as well as specific volumes of vapors, it is evident that the cylinder displacements will be individual with each kind of refrigerant. Those refrigerants which have high refrigerating effects with corresponding low specific volumes of vapor, will require the minimum cylinder displacements, while those which have low refrigerating effects, and correspondingly large specific volumes of vapor, will require the maximum cylinder displacements. The converse of this may be stated by giving the refrigerating effect per cubic foot of cylinder displacement. Table XIII has been prepared to show the relative refrigeration per cubic foot of cylinder displacement for an evaporating temperature of 5° F., and a condensing temperature of 86° F. for some of the common refrigerants. From this table, it will be noted

that ethyl chloride has a very small refrigerating effect per cubic foot of cylinder displacement, that carbon dioxide has a high refrigerating effect per cubic foot, and that sulphur dioxide, methyl chloride, and ammonia, have a medium refrigerating effect per cubic foot of cylinder displacement.

TABLE XIII—COMPARATIVE REFRIGERATION PER CU. FT. OF CYLINDER DISPLACEMENT

For 5° F. Suction Temperature and 86° F. Condensing Temperature

	Sulphur Dioxide	Ammonia	Methyl Chloride	Carbon Dioxide	Ethyl Chloride
Chemical Symbol....	SO_2	NH_3	CH_3CL	CO_2	C_2H_5CL
Latent Heat at 5° F...	169.38	565.0	178.56	115.3	177.0
Heat to Cool Liquid.....	28.01	90.55	38.15	58.61	34.7
Refrigerating Effect per lb.	141.37	474.45	140.41	56.69	142.3
Specific Volume Vapor at 5° F. (cu. ft. per lb.)...	6.421	8.15	4.53	0.2673	17.06
Refrigerating Effect per cu. ft. Cylinder Displacement.	22.17	58.22	31.00	212.08	8.35

Properties of Ammonia.—Ammonia is a colorless, gaseous compound of nitrogen and hydrogen. Its chemical formula is NH_3, indicating that one atom of nitrogen unites with three atoms of hydrogen to form ammonia. Its boiling point at atmospheric pressure is —28° F. It has a melting point of —107.86° F.

Color and Odor.—Ammonia is a colorless, transparent liquid or gas. It has an extremely pungent, peculiar, and offensive odor which is easily recognizable and irrespirable.

Inflammability.—It does not support combustion. However, under high pressure it may form an explosive mixture when intermingled with oil vapor. It is decomposed into its elements by extreme heat and under such conditions, an explosive mixture may result. It is combustible when mixed with a sufficient proportion of air, being capable of exploding with considerable violence.

Corrosion of Metals.—It will attack copper and all of its alloys when water is present, but it has no chemical or corrosive action on iron and steel. Ammonium hydroxide has a

slight reaction on iron when in a very dilute concentration. With the higher concentrations used in ammonia absorption plants, no reaction occurs on iron.

Locating Leaks. — Ammonia leaks may be readily located by the "smoke" test which consists of placing a burning sulphur stick in the vicinity of the leak. A chemical reaction occurs and a dense white smoke apparently issues from the opening.

Stability Toward Heat.—It is a rather stable gas especially at temperatures under 300° F. However, the chemical bond is not as strong as with carbon dioxide and sulphur dioxide. A household compressor should always have a discharge gas temperature lower than 300° F.

Solubility in Water.—It is very soluble in water, the union of the two producing considerable heat and forming ammonium hydroxide until a certain concentration has been reached. The vapor may then be driven off by heating the ammonium hydroxide, and it is on this principle that the absorption system operates.

Properties of Butane.—Butane is one of the isomeric, inflammable gaseous hydrocarbons of the methane series. Its chemical formula is C_4H_{10}, indicating that four atoms of carbon unite with ten atoms of hydrogen to form butane. It has a boiling point of 31° F. at normal atmospheric pressure and a melting point of 211° F.

Color and Odor.—Butane is a colorless liquid or gas, with a slight ethereal odor and is slightly asphyxiating. The vapor is non-poisonous.

Inflammability. — It is inflammable, the gas burning with a yellow flame.

Corrosion of Metals. — It has no corosive effect on copper, copper alloys or iron, even in the presence of moisture.

Locating Leaks. — It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—It is a stable gas which does not break up at temperatures encountered in normal operation. The critical temperature is 551.3° F.

Displacement Required. — The displacement required for a certain amount of refrigeration is about 7 per cent more than with sulphur dioxide.

Properties of Carbon Dioxide (Carbonic Acid Gas).—Carbon dioxide is a heavy, colorless gas; it is sometimes called carbonic acid gas. This is on account of the fact that the acid, carbonic acid, H_2CO_3 breaks down readily into water and carbon dioxide, CO_2; the latter is commonly called carbon dioxide or carbonic acid gas. It has a chemical symbol, CO_2, which indicates that one atom of carbon unites with two atoms of oxygen to form carbon dioxide. At normal atmospheric pressure, it has a boiling temperature of —108.4° F. and if the liquid is sufficiently cooled, it is solidified into a snowlike substance, which evaporizes or sublimes at —160.6° F.

Color and Odor. — Carbon dioxide, sometimes called carbonic acid gas, is a colorless liquid or gas. It exists as a gas in very small quantities in the atmosphere and is non-odorous. It is harmless to breathe except in extremely large concentrations when the lack of oxygen would be noticed.

Inflammability. — It is not inflammable and does not support combustion.

Corrosion of Metals.—It has no corosive effect on copper, copper alloys or iron.

Locating Leaks. — It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—It is a stable gas which does not break up at the temperature encountered in normal operation. This gas is very inert. The critical temperature is 87.80° F.

Solubility in Water. — It is slightly soluble in water, the percentage increasing at lower temperatures.

Displacement Required. — It requires about one-fourth the displacement of an ammonia machine to do the same amount of refrigeration.

Properties of Ethane.—Ethane is a gaseous hydrocarbon, and is a constituent of ordinary natural and illuminating gas. It is a second member of the methane series, and has the chemical symbol C_2H_6. It has a boiling point of —126.9° F. and a melting point of —277.6° F.

Color and Odor. — Ethane is a colorless liquid or gas of the hydrocarbon series. The gas is non-poisonous. It has an ethereal odor and is slightly asphyxiating.

Inflammability. — It is inflammable, burning with a yellow flame.

Corrosion of Metals. — It has no corrosive effect on metals and does not form injurious acids with water.

Locating Leaks. — It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat. — This gas is stable under the conditions of pressure and temperature required in refrigeration work.

Displacement Required. — The displacement required is about 40 per cent greater than with carbon dioxide.

Properties of Ether.—Ether is a light, volatile, inflammable gas, having a characteristic aromatic odor, and is obtained by the distillation of alcohol with sulphuric acid, and is thus sometimes termed "sulphuric ether." It has the chemical symbol $C_4H_{10}O$. Its boiling point is 94.1° F., and its melting point is —177.34° F.

Color and Odor. — Ether is a colorless gas or liquid with a strong ethereal smell.

Inflammability. — It burns with a luminous flame and explodes when mixed with air.

Corrosion of Metals. — It has no corrosive action on metals

Locating Leaks.—It is difficult to locate leaks, especially on the evaporating side, as this is usually operating at a vacuum. Air leaking into the system would cause no damage

from chemical action or corrosion; however, it would soon increase the condensing pressure, affecting the normal operation of the system.

Stability Towards Heat.—It is stable at the temperatures reached in the condensing element. The gas condenses during compression and superheats during expansion.

It is miscible with water.

Properties of Ethyl Chloride.—Ethyl chloride is a colorless and a very volatile liquid, having an aromatic odor. It is used widely as a local anaesthetic. Its chemical symbol is C_2H_5Cl. It has a boiling point of 53.96° F., and a melting point of —217.66° F.

Color and Odor. — Ethyl chloride is a colorless gas or liquid with a pungent ethereal smell and a sweetish taste.

Inflammability. — It is inflammable when mixed with a certain proportion of air. It burns with a green-edged flame. A certain quality of ethyl chloride has been produced in England which is claimed to be non-inflammable. This result is obtained by the addition of a certain amount of methyl bromide.

Corrosion of Metals. — It has no corrosive effect on metals.

Locating Leaks. — It is very difficult to locate leaks, especially on the evaporating side of the system, as the pressure of evaporization is considerably below atmospheric pressure.

Stability Towards Heat. — It is stable toward heat and does not fractionize at the temperatures reached in the condenser. The critical temperature is 361.0° F.

Solubility in Water.—It is slightly soluble in water and dissolves oils. Glycerine is used as a lubricant in some ethyl chloride systems.

Properties of Methyl Chloride. — Methyl chloride is the colorless, sweet-smelling gas which is obtained by the action of hydrochloric acid on methyl alcohol. It is easily liquefied by pressure and cold, and is used as a refrigerant and a local anaesthetic. It has a chemical symbol of CH_3Cl, and has a boiling point of —10.66° F., and a melting point of —143.68° F.

Color and Odor.—Methyl chloride is a colorless, transparent liquid or gas. The odor resembles that of chloroform; however, it is not so heavy and is less sweet.

Inflammability. — It is inflammable in concentrations of at least 10 per cent and not more than 15 per cent with air. It requires a spark or white hot wire to explode it even at these concentrations.

Corrosion of Metals.—It does not attack copper, copper alloys or iron.

Locating Leaks.—Methyl chloride operates with a pressure greater than atmospheric on both the condensing and evaporating units of the system. A large leak would force methyl chloride gas into the room where its presence might be noticed by the peculiar odor. One method of testing for leaks is by means of an alcohol flame, for methyl chloride gas will impart a green color to the nearly colorless alcohol flame.

Stability Towards Heat.—It is very stable towards heat. It requires a red heat to decompose it into hydrochloric acid, methane, hydrogen, etc. The critical temperature is 289.6° F.

Solubility in Water.—Three to four volumes of methyl chloride gas will dissolve into one volume of water at ordinary temperature and atmospheric pressure. Methyl chloride in the presence of water may form a solid crystalline hydrate $CH_3C1.6.H_2O$.

Properties of Propane.—Propane is one of the heavy gaseous hydrocarbons of the paraffin series. It occurs, naturally, dissolved in crude petroleum. It has the chemical symbol C_3H_8, a boiling point of —48.1° F., and a melting point of —309.8° F.

Color and Odor.—Propane is a colorless liquid or gas of the hydrocarbon series. The gas is non-poisonous and is not dangerous to breathe until its density is sufficient to exclude the oxygen necessary during respiration. It has an ethereal odor and is slightly asphyxiating.

Inflammability.—It is inflammable. The gas burns with a yellow flame.

Corrosion of Metals.—It has no corrosive action on any metals and does not form injurious acids with water.

Locating Leaks.—It is difficult to locate leaks as no easy sight test can be made.

Stability Towards Heat.—It is stable under the conditions required in refrigeration work. The critical temperature is 204.1° F.

Displacement Required.—The displacement required is practically the same as with ammonia.

Properties of Sulphur Dioxide.—Sulphur dioxide is a colorless gas, having a pungent, suffocating odor. It is produced by the burning of sulphur. It has a chemical symbol, SO_2, and a boiling point of 14° F., and a melting point of —98.86° F.

Color and Odor.—Sulphur dioxide is a colorless liquid or gas. The gas is non-poisonous.

Inflammability. — It is not inflammable and does not support combustion.

Corrosion of Metals.—It has no corrosive effect on copper, copper alloys or iron. If there is water present, sulphurous acid is formed which will have a chemical action on metals such as iron, zinc, or copper. The moisture should be under 0.3 per cent by volume for commercial use.

Locating Leaks.—It is easy to locate leaks by a smoke test, using ammonia water applied with a brush.

Stability Towards Heat.—It is a very stable gas which will easily withstand the temperature conditions encountered in normal operation. The critical temperature is 314.8° F. The critical pressure is 1141.5 pounds per square inch absolute.

Solubility in Water.—One volume of water dissolves 80 volumes of this gas at 32° F., and 47.3 volumes at 60° F.

Displacement Required.—It requires about 2.6 times the displacement of an ammonia machine for the same amount of refrigeration.

Air.—Air was used as the refrigerant in some of the early machines. It was compressed, cooled to room temperature, and then expanded in a cylinder. These machines were very inefficient because of the large volume of air handled, which together with the expansion cylinder, caused large friction losses. Air has a very low heat capacity per unit volume. Considerable difficulty was experienced with the moisture freezing and clogging valves. The advantages of using air such as safety from leakage do not compensate for the disadvantages stated above.

Two general types of air machines have been produced. These are the open and closed cycle. The open cycle type continually uses new air from the atmosphere. There is considerable trouble from condensing and freezing water vapor within the apparatus. The closed cycle eliminates this dis advantage.

Water as a Refrigerant.—Several machines have been developed using water as the refrigerant. At a low vacuum water boils at temperatures as follows:

Vacuum, ins. of mercury	29.74	29.67	29.56	29.40
Boiling temperature	32°F.	40°F.	50°F.	60°F.

It is difficult to produce a commercial pump to obtain such a low vacuum. The air in the water must also be discharged.

Sulphuric acid is used to absorb the water in some systems of this kind. A pump must be used to remove the air.

Small hand machines are made in Europe to operate on this system. They will cool a carafe of water in a few minutes or make a few pounds of ice in less than half an hour. This type of machine is used extensively in the tropics.

Non-Condensable Gases.—It is important to prevent the formation of non-condensing gases in a household ammonia absorption refrigerating machine. These gases are eliminated on the larger plants by frequent purging.

The United States Bureau of Standards has recently made a careful study of this subject and recommends the following method of eliminating, to a large extent, the formation of these gases:

1. The non-condensable gases found in ammonia absorption refrigeration machines are due to either or both of two causes, namely, (a) leaks of air into the system and (b) the corrosive action of the ammonia liquor on the metal of the plant.

2. When the foul air gas is mainly nitrogen, the gas is derived from air that has leaked into the system, and leaks should therefore be sought. The oxygen in the air is very quickly used up, and so will be present in only a very small percentage of its original amount. If the foul gas is hydrogen, the cause is corrosion by the ammoniacal liquor. A gas containing both nitrogen and hydrogen shows both causes to be present.

3. If a solution of sodium or potassium dichromate is added to the generator charge so that the charge in the generator will contain the salt to the extent of 0.2 per cent by weight, all foul gas formation from the corrosive action of the ammonia charge will be stopped. It is recommended that the dichromate be added in all cases, as it has been found that its presence decreases the very small amount of gas caused by even the highest grade ammonias.

Explosion Data on Gases.—The following explosion data on refrigerating and illuminating gases was taken from a report on refrigerating with gas presented at a meeting of the American Gas Association, 1925.

TABLE XIV.—EXPLOSION DATA ON GASES

	Ammonia	Ethyl Chloride	Methyl Chloride	Illuminating Gas
Relative parts of diffusion (Air = 1)	1.301	0.658	0.750	1.240
Gas in mixture required for complete combustion (%)	21.83	6.05	10.69	17.00
Apparent ignition temperature (°F.)	No values available			1094
Explosion limits with air—				
High (%)	26.8	14.0	15.0	21.0
Low (%)	13.1	4.3	8.9	7.0
Explosion pressures with air (lbs. sq. in)	54	98	81	95
Time required to develop maximum pressure (seconds)	0.175	0.049	0.099	0.017

Relative Piston Displacement for Refrigerants.—As previously indicated, the relative piston displacement for the compressor cylinder depends upon a number of factors, such as a latent heat of evaporization, sensible heat of the liquid, relative specific volume, etc. Table XV has been prepared to show

the comparative displacements of the various refrigerants indicated when compared with the displacement required by carbon dioxide.

TABLE XV.—RELATIVE PISTON DISPLACEMENT FOR VARIOUS REFRIGERANTS

Carbon dioxide	= 1.
Ammonia	= 3.6
Methyl Chloride	= 6.8
Sulphur Dioxide	= 9.6
Ethyl Chloride	= 25.4

Solubility of Sulphur Dioxide in Water. — Weights in grams of sulphur dioxide gas which will be absorbed in 1,000 grams of water when the partial pressure of the liquid at the given temperature equals 700 millimeters are as follows:

0° C.	10° C.	20° C.	30° C.	40° C.
228	162	113	78	54

(This was compiled from Landoit-Börnstein-Meyerhoffers "Physikalisch-Chemische Tabellen.")

Charging Refrigerants.—Refrigerants may be charged into refrigerating systems or thermostats in many different ways. Following are some of the principles used in this refrigerant charging process:

There are two simple methods of charging the liquid refrigerant from container A to container B in Fig. 3. It is assumed that the air has been exhausted from these containers and the connecting line. The container B may be at a higher elevation than A. By heating container A, the liquid is evaporated and slowly condenses in B. This is a slow process as sufficient heat must be applied to A to heat and evaporate the liquid refrigerant and enough heat must be extracted from B to condense the gas. Another method is to apply ice or cool B.

When the outlet pipe from C is below the liquid level in C the liquid refrigerant will pass to D in liquid form. It is only necessary to either warm C or cool D. This establishes a pressure difference which readily forces the liquid into container D.

In charging household systems, it is customary to first use a vacuum pump to eliminate the air and moisture from the refrigerating system. Then the refrigerant is charged in liquid

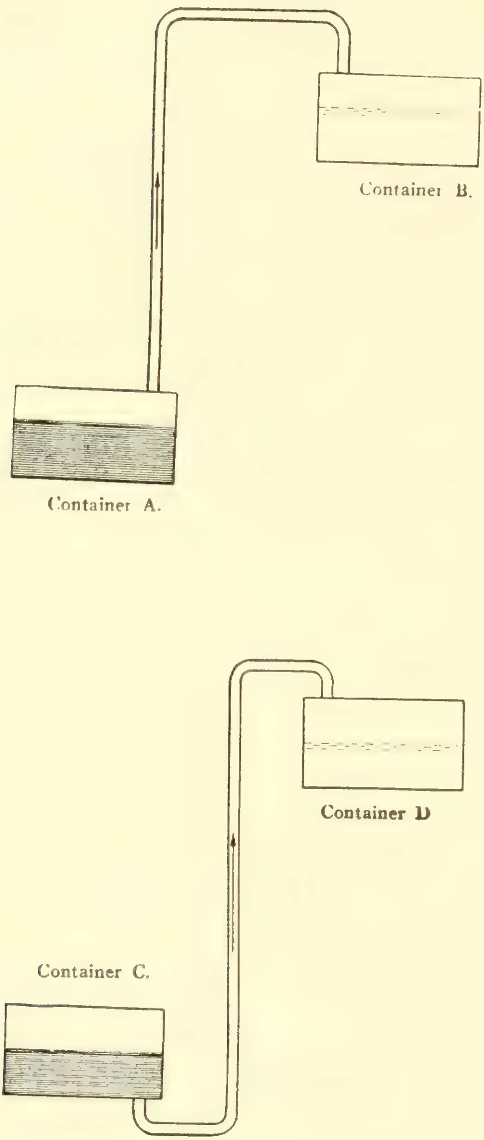

FIG. 3.—CHARGING OF REFRIGERANTS.

form. The amount of charge is regulated by weighing or using a glass liquid gauge on the charging receiver.

It is extremely dangerous to heat a cylinder containing liquid refrigerant. When the pressure drops in charging it is probably best to place the cylinder in a bucket of water in order to supply sufficient heat to evaporate the liquid refrigerant from the cylinder rapidly.

In charging a thermostat, it is very important to first eliminate the air. The best method is to use a vacuum pump, although it is possible to eliminate practically all of the air by repeatedly charging and discharging the thermostat bulb and line with the gas to be used. The liquid should fill about two-thirds of the bulb. An overcharged thermostat may cause considerable trouble.

Method of Determining the Density of a Gas.—The volume of any gas may be approximately determined from its molecular weight at atmospheric pressure of 14.7 lbs. and 60° F., as follows:

$$\text{Weight per cu. ft.} = \frac{\text{molecular weight}}{376}$$

$$\text{Cu. ft. per pound} = \frac{376}{\text{molecular weight}}$$

The volume of one cu. ft. of sulphur dioxide gas at 14.7 lbs. atmospheric pressure and 60° F. would be found as follows:

$$\frac{64}{376} = 0.170 \text{ lbs.}$$

The volume in cu. ft. per pound is found as follows:

$$\frac{376}{64} = 5.87$$

TABLE XVI.—MOLECULAR WEIGHT OF GASES

Gas	Molecular Weight
Nitrogen—N_2	28
Oxygen—O_2	32
Carbon Dioxide—CO_2	44
Sulphur Dioxide—SO_2	64
Hydrogen—H_2	2
Ammonia—NH_3	17
Air	28.8

CHAPTER IV.

REFRIGERANTS—TABLES.

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TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(*Continued.*)

Temp. °F.	Pressure.		Volume vapor. ft³ lb.	Density vapor. lbs. ft.³	Heat content.		Latent heat. Btu./lb.	Entropy.		Temp. °F.
	Absolute. lbs. in.²	Gage. lbs./in.²			Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb.°F.	Vapor. Btu./lb.°F.	
t	p	$g.p.$	V	$1/V$	h	H	L	s	S	t
−60	5.55	*18.6	44.73	0.02235	−21.2	589.6	610.8	−0.0517	1.4769	**−60**
−59	5.74	*18.2	43.37	.02306	−20.1	590.0	610.1	−.0490	.4741	−59
−58	5.93	*17.8	42.05	.02378	−19.1	590.4	609.5	−.0464	.4713	−58
−57	6.13	*17.4	40.79	.02452	−18.0	590.8	608.8	−.0438	.4686	−57
−56	6.33	*17.0	39.56	.02528	−17.0	591.2	608.2	−.0412	.4658	−56
−55	6.54	*16.6	38.38	0.02605	−15.9	591.6	607.5	−0.0386	1.4631	**−55**
−54	6.75	*16.2	37.24	.02685	−14.8	592.1	606.9	.0360	.4604	−54
−53	6.97	*15.7	36.15	.02766	−13.8	592.4	606.2	−.0334	.4577	−53
−52	7.20	*15.3	35.09	.02850	−12.7	592.9	605.6	−.0307	.4551	−52
−51	7.43	*14.8	34.06	.02936	−11.7	593.2	604.9	−.0281	.4524	−51
−50	7.67	*14.3	33.08	0.03023	−10.6	593.7	604.3	−0.0256	1.4497	**−50**
−49	7.91	*13.8	32.12	.03113	−9.6	594.0	603.6	−.0230	.4471	−49
−48	8.16	*13.3	31.20	.03205	−8.5	594.4	602.9	−.0204	4445	−48
−47	8.42	*12.8	30.31	.03299	−7.4	594.9	602.3	−.0179	.4419	−47
−46	8.68	*12.2	29.45	.03395	−6.4	595.2	601.6	−.0153	.4393	−46
−45	8.95	*11.7	28.62	0.03494	−5.3	595.6	600.9	−0.0127	1.4368	**−45**
−44	9.23	*11.1	27.82	.03595	−4.3	596.0	600.3	−.0102	.4342	−44
−43	9.51	*10.6	27.04	.03698	−3.2	596.4	599.6	−.0076	.4317	−43
−42	9.81	*10.0	26.29	.03804	−2.1	596.8	598.9	−.0051	.4292	−42
−41	10.10	*9.3	25.56	.03912	−1.1	597.2	598.3	−.0025	.4267	−41
−40	10.41	*8.7	24.86	0.04022	0.0	597.6	597.6	0.0000	1.4242	**−40**
−39	10.72	*8.1	24.18	.04135	1.1	598.0	596.9	.0025	.4217	−39
−38	11.04	*7.4	23.53	.04251	2.1	598.3	596.2	.0051	.4193	−38
−37	11.37	*6.8	22.89	.04369	3.2	598.7	595.5	.0076	.4169	−37
−36	11.71	*6.1	22.27	.04489	4.3	599.1	594.8	.0101	.4144	−36
−35	12.05	*5.4	21.68	0.04613	5.3	599.5	594.2	0.0126	1.4120	**−35**
−34	12.41	*4.7	21.10	.04739	6.4	599.9	593.5	.0151	.4096	−34
−33	12.77	*3.9	20.54	.04868	7.4	600.2	592.8	.0176	.4072	−33
−32	13.14	*3.2	20.00	.04999	8.5	600.6	592.1	.0201	.4048	−32
−31	13.52	*2.4	19.48	.05134	9.6	601.0	591.4	.0226	.4025	−31
−30	13.90	*1.6	18.97	0.05271	10.7	601.4	590.7	0.0250	1.4001	**−30**
−29	14.30	*0.8	18.48	.05411	11.7	601.7	590.0	.0275	.3978	−29
−28	14.71	0.0	18.00	.05555	12.8	602.1	589.3	.0300	.3955	−28
−27	15.12	0.4	17.54	.05701	13.9	602.5	588.6	.0325	.3932	−27
−26	15.55	0.8	17.09	.05850	14.9	602.8	587.9	.0350	.3909	−26
−25	15.98	1.3	16.66	0.06003	16.0	603.2	587.2	0.0374	1.3886	**−25**
−24	16.42	1.7	16.24	.06158	17.1	603.6	586.5	.0399	.3863	−24
−23	16.88	2.2	15.83	.06317	18.1	603.9	585.8	.0423	.3840	−23
−22	17.34	2.6	15.43	.06479	19.2	604.3	585.1	.0448	.3818	−22
−21	17.81	3.1	15.05	.06644	20.3	604.6	584.3	.0472	.3796	−21
−20	18.30	3.6	14.68	0.06813	21.4	605.0	583.6	0.0497	1.3774	**−20**
−19	18.79	4.1	14.32	.06985	22.4	605.3	582.9	.0521	.3752	−19
−18	19.30	4.6	13.97	.07161	23.5	605.7	582.2	.0545	.3729	−18
−17	19.81	5.1	13.62	.07340	24.6	606.1	581.5	.0570	.3708	−17
−16	20.34	5.6	13.29	.07522	25.6	606.4	580.8	.0594	.3686	−16
−15	20.88	6.2	12.97	0.07709	26.7	606.7	580.0	0.0618	1.3664	**−15**
−14	21.43	6.7	12.66	.07898	27.8	607.1	579.3	.0642	.3643	−14
−13	21.99	7.3	12.36	.08092	28.9	607.5	578.6	.0666	.3621	−13
−12	22.56	7.9	12.06	.08289	30.0	607.8	577.8	.0690	.3600	−12
−11	23.15	8.5	11.78	.08490	31.0	608.1	577.1	.0714	.3579	−11
−10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4	0.0738	1.3558	**−10**

* Inches of mercury below one standard atmosphere (29.92 in.).

TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(*Continued.*)

Temp. °F.	Pressure. Absolute. lbs./in.²	Pressure. Gage. lbs./in.²	Volume vapor. ft³/lb.	Density vapor. lbs./ft.³	Heat content. Liquid. Btu./lb.	Heat content. Vapor. Btu./lb.	Latent heat. Btu./lb.	Entropy. Liquid. Btu./lb.°F.	Entropy. Vapor. Btu./lb.°F.	Temp. °F.
t	p	$g.p.$	V	$1/V$	h	H	L	s	S	t
−10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4	0.0738	1.3558	**−10**
−9	24.35	9.7	11.23	.08904	33.2	608.8	575.6	.0762	.3537	−9
−8	24.97	10.3	10.97	.09117	34.3	609.2	574.9	.0786	.3516	−8
−7	25.61	10.9	10.71	.09334	35.4	609.5	574.1	.0809	.3495	−7
−6	26.26	11.6	10.47	.09555	36.4	609.8	573.4	.0833	.3474	−6
−5	26.92	12.2	10.23	0.09780	37.5	610.1	572.6	0.0857	1.3454	**−5**
−4	27.59	12.9	9.991	.1001	38.6	610.5	571.9	.0880	.3433	−4
−3	28.28	13.6	9.763	.1024	39.7	610.8	571.1	.0904	.3413	−3
−2	28.98	14.3	9.541	.1048	40.7	611.1	570.4	.0928	.3393	−2
−1	29.69	15.0	9.326	.1072	41.8	611.4	569.6	.0951	.3372	−1
0	30.42	15.7	9.116	0.1097	42.9	611.8	568.9	0.0975	1.3352	**0**
1	31.16	16.5	8.912	.1122	44.0	612.1	568.1	.0998	.3332	1
2	31.92	17.2	8.714	.1148	45.1	612.4	567.3	.1022	.3312	2
3	32.69	18.0	8.521	.1174	46.2	612.7	566.5	.1045	.3292	3
4	33.47	18.8	8.333	.1200	47.2	613.0	565.8	.1069	.3273	4
5	34.27	19.6	8.150	0.1227	48.3	613.3	565.0	0.1092	1.3253	**5**
6	35.09	20.4	7.971	.1254	49.4	613.6	564.2	.1115	.3234	6
7	35.92	21.2	7.798	.1282	50.5	613.9	563.4	.1138	.3214	7
8	36.77	22.1	7.629	.1311	51.6	614.3	562.7	.1162	.3195	8
9	37.63	22.9	7.464	.1340	52.7	614.6	561.9	.1185	.3176	9
10	38.51	23.8	7.304	0.1369	53.8	614.9	561.1	0.1208	1.3157	**10**
11	39.40	24.7	7.148	.1399	54.9	615.2	560.3	.1231	.3137	11
12	40.31	25.6	6.996	.1429	56.0	615.5	559.5	.1254	.3118	12
13	41.24	26.5	6.847	.1460	57.1	615.8	558.7	.1277	.3099	13
14	42.18	27.5	6.703	.1492	58.2	616.1	557.9	.1300	.3081	14
15	43.14	28.4	6.562	0.1524	59.2	616.3	557.1	0.1323	1.3062	**15**
16	44.12	29.4	6.425	.1556	60.3	616.6	556.3	.1346	.3043	16
17	45.12	30.4	6.291	.1590	61.4	616.9	555.5	.1369	.3025	17
18	46.13	31.4	6.161	.1623	62.5	617.2	554.7	.1392	.3006	18
19	47.16	32.5	6.034	.1657	63.6	617.5	553.9	.1415	.2988	19
20	48.21	33.5	5.910	0.1692	64.7	617.8	553.1	0.1437	1.2969	**20**
21	49.28	34.6	5.789	.1728	65.8	618.0	552.2	.1460	.2951	21
22	50.36	35.7	5.671	.1763	66.9	618.3	551.4	.1483	.2933	22
23	51.47	36.8	5.556	.1800	68.0	618.6	550.6	.1505	.2915	23
24	52.59	37.9	5.443	.1837	69.1	618.9	549.8	.1528	.2897	24
25	53.73	39.0	5.334	0.1875	70.2	619.1	548.9	0.1551	1.2879	**25**
26	54.90	40.2	5.227	.1913	71.3	619.4	548.1	.1573	.2861	26
27	56.08	41.4	5.123	.1952	72.4	619.7	547.3	.1596	.2843	27
28	57.28	42.6	5.021	.1992	73.5	619.9	546.4	.1618	.2825	28
29	58.50	43.8	4.922	.2032	74.6	620.2	545.6	.1641	.2808	29
30	59.74	45.0	4.825	0.2073	75.7	620.5	544.8	0.1663	1.2790	**30**
31	61.00	46.3	4.730	.2114	76.8	620.7	543.9	.1686	.2773	31
32	62.29	47.6	4.637	.2156	77.9	621.0	543.1	.1708	.2755	32
33	63.59	48.9	4.547	.2199	79.0	621.2	542.2	.1730	.2738	33
34	64.91	50.2	4.459	.2243	80.1	621.5	541.4	.1753	.2721	34
35	66.26	51.6	4.373	0.2287	81.2	621.7	540.5	0.1775	1.2704	**35**
36	67.63	52.9	4.289	.2332	82.3	622.0	539.7	.1797	.2686	36
37	69.02	54.3	4.207	.2377	83.4	622.2	538.8	.1819	.2669	37
38	70.43	55.7	4.126	.2423	84.6	622.5	537.9	.1841	.2652	38
39	71.87	57.2	4.048	.2470	85.7	622.7	537.0	.1863	.2635	39
40	73.32	58.6	3.971	0.2518	86.8	623.0	536.2	0.1885	1,2618	**40**

TABLE XVII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(*Continued.*)

Temp. °F.	Pressure		Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Heat content.		Latent heat. Btu./lb.	Entropy.		Temp. °F.
	Absolute lbs./in.²	Gage. lbs./in.²			Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb.°F.	Vapor. Btu./lb.°F.	
t	*p*	*g. p.*	*V*	*1/V*	*h*	*H*	*L*	*s*	*S*	*t*
40	73.32	58.6	3.971	0.2518	86.8	623.0	536.2	0.1885	1.2618	**40**
41	74.80	60.1	3.897	.2566	87.9	623.2	535.3	.1908	.2602	41
42	76.31	61.6	3.823	.2616	89.0	623.4	534.4	.1930	.2585	42
43	77.83	63.1	3.752	.2665	90.1	623.7	533.6	.1952	.2568	43
44	79.38	64.7	3.682	.2716	91.2	623.9	532.7	.1974	.2552	44
45	80.96	66.3	3.614	0.2767	92.3	624.1	531.8	0.1996	1.2535	**45**
46	82.55	67.9	3.547	.2819	93.5	624.4	530.9	.2018	.2519	46
47	84.18	69.5	3.481	.2872	94.6	624.6	530.0	.2040	.2502	47
48	85.82	71.1	3.418	.2926	95.7	624.8	529.1	.2062	.2486	48
49	87.49	72.8	3.355	.2981	96.8	625.0	528.2	.2083	.2469	49
50	89.19	74.5	3.294	0.3036	97.9	625.2	527.3	0.2105	1.2453	**50**
51	90.91	76.2	3.234	.3092	99.1	625.5	526.4	.2127	.2437	51
52	92.66	78.0	3.176	.3149	100.2	625.7	525.5	.2149	.2421	52
53	94.43	79.7	3.119	.3207	101.3	625.9	524.6	.2171	.2405	53
54	96.23	81.5	3.063	.3265	102.4	626.1	523.7	.2192	.2389	54
55	98.06	83.4	3.008	0.3325	103.5	626.3	522.8	0.2214	1.2373	**55**
56	99.91	85.2	2.954	.3385	104.7	626.5	521.8	.2236	.2357	56
57	101.8	87.1	2.902	.3446	105.8	626.7	520.9	.2257	.2341	57
58	103.7	89.0	2.851	.3508	106.9	626.9	520.0	.2279	.2325	58
59	105.6	90.9	2.800	.3571	108.1	627.1	519.0	.2301	.2310	59
60	107.6	92.9	2.751	0.3635	109.2	627.3	518.1	0.2322	1.2294	**60**
61	109.6	94.9	2.703	.3700	110.3	627.5	517.2	.2344	.2278	61
62	111.6	96.9	2.656	.3765	111.5	627.7	516.2	.2365	.2262	62
63	113.6	98.9	2.610	.3832	112.6	627.9	515.3	.2387	.2247	63
64	115.7	101.0	2.565	.3899	113.7	628.0	514.3	.2408	.2231	64
65	117.8	103.1	2.520	0.3968	114.8	628.2	513.4	0.2430	1.2216	**65**
66	120.0	105.3	2.477	.4037	116.0	628.4	512.4	.2451	.2201	66
67	122.1	107.4	2.435	.4108	117.1	628.6	511.5	.2473	.2186	67
68	124.3	109.6	2.393	.4179	118.3	628.8	510.5	.2494	.2170	68
69	126.5	111.8	2.352	.4251	119.4	628.9	509.5	.2515	.2155	69
70	128.8	114.1	2.312	0.4325	120.5	629.1	508.6	0.2537	1.2140	**70**
71	131.1	116.4	2.273	.4399	121.7	629.3	507.6	.2558	.2125	71
72	133.4	118.7	2.235	.4474	122.8	629.4	506.6	.2579	.2110	72
73	135.7	121.0	2.197	.4551	124.0	629.6	505.6	.2601	.2095	73
74	138.1	123.4	2.161	.4628	125.1	629.8	504.7	.2622	.2080	74
75	140.5	125.8	2.125	0.4707	126.2	629.9	503.7	0.2643	1.2065	**75**
76	143.0	128.3	2.089	.4786	127.4	630.1	502.7	.2664	.2050	76
77	145.4	130.7	2.055	.4867	128.5	630.2	501.7	.2685	.2035	77
78	147.9	133.2	2.021	.4949	129.7	630.4	500.7	.2706	.2020	78
79	150.5	135.8	1.988	.5031	130.8	630.5	499.7	.2728	.2006	79
80	153.0	138.3	1.955	0.5115	132.0	630.7	498.7	0.2749	1.1991	**80**
81	155.6	140.9	1.923	.5200	133.1	630.8	497.7	.2769	.1976	81
82	158.3	143.6	1.892	.5287	134.3	631.0	496.7	.2791	.1962	82
83	161.0	146.3	1.861	.5374	135.4	631.1	495.7	.2812	.1947	83
84	163.7	149.0	1.831	.5462	136.6	631.3	494.7	.2833	.1933	84
85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6	0.2854	1.1918	**85**

TABLE XVII. BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: TEMPERATURE TABLE.—(*Continued.*)

	Pressure.				Heat content.			Entropy.		
Temp. °F.	Absolute. lbs./in.²	Gage. lbs./in.²	Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Liquid. Btu./lb.	Vapor. Btu./lb.	Latent heat. Btu./lb.	Liquid. Btu./lb.°F.	Vapor. Btu./lb.°F.	Temp. °F.
t	p	$g.p.$	V	$1/V$	h	H	L	s	S	t
85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6	0.2854	1.1918	**85**
86	169.2	154.5	1.772	.5643	138.9	631.5	492.6	.2875	.1904	86
87	172.0	157.3	1.744	.5735	140.1	631.7	491.6	.2895	.1889	87
88	174.8	160.1	1.716	.5828	141.2	631.8	490.6	.2917	.1875	88
89	177.7	163.0	1.688	.5923	142.4	631.9	489.5	.2937	.1860	89
90	180.6	165.9	1.661	0.6019	143.5	632.0	488.5	0.2958	1.1846	**90**
91	183.6	168.9	1.635	.6116	144.7	632.1	487.4	.2979	.1832	91
92	186.6	171.9	1.609	.6214	145.8	632.2	486.4	.3000	.1818	92
93	189.6	174.9	1.584	.6314	147.0	632.3	485.3	.3021	.1804	93
94	192.7	178.0	1.559	.6415	148.2	632.5	484.3	.3041	.1789	94
95	195.8	181.1	1.534	0.6517	149.4	632.6	483.2	0.3062	1.1775	**95**
96	198.9	184.2	1.510	.6620	150.5	632.6	482.1	.3083	.1761	96
97	202.1	187.4	1.487	.6725	151.7	632.8	481.1	.3104	.1747	97
98	205.3	190.6	1.464	.6832	152.9	632.9	480.0	.3125	.1733	98
99	208.6	193.9	1.441	.6939	154.0	632.9	478.9	.3145	.1719	99
100	211.9	197.2	1.419	0.7048	155.2	633.0	477.8	0.3166	1.1705	**100**
101	215.2	200.5	1.397	.7159	156.4	633.1	476.7	.3187	.1691	101
102	218.6	203.9	1.375	.7270	157.6	633.2	475.6	.3207	.1677	102
103	222.0	207.3	1.354	.7384	158.7	633.3	474.6	.3228	.1663	103
104	225.4	210.7	1.334	.7498	159.9	633.4	473.5	.3248	.1649	104
105	228.9	214.2	1.313	0.7615	161.1	633.4	472.3	0.3269	1.1635	**105**
106	232.5	217.8	1.293	.7732	162.3	633.5	471.2	.3289	.1621	106
107	236.0	221.3	1.274	.7852	163.5	633.6	470.1	.3310	.1607	107
108	239.7	225.0	1.254	.7972	164.6	633.6	469.0	.3330	.1593	108
109	243.3	228.6	1.235	.8095	165.8	633.7	467.9	.3351	.1580	109
110	247.0	232.3	1.217	0.8219	167.0	633.7	466.7	0.3372	1.1566	**110**
111	250.8	236.1	1.198	.8344	168.2	633.8	465.6	.3392	.1552	111
112	254.5	239.8	1.180	.8471	169.4	633.8	464.4	.3413	.1538	112
113	258.4	243.7	1.163	.8600	170.6	633.9	463.3	.3433	.1524	113
114	262.2	247.5	1.145	.8730	171.8	633.9	462.1	.3453	.1510	114
115	266.2	251.5	1.128	0.8862	173.0	633.9	460.9	0.3474	1.1497	**115**
116	270.1	255.4	1.112	.8996	174.2	634.0	459.8	.3495	.1483	116
117	274.1	259.4	1.095	.9132	175.4	634.0	458.6	.3515	.1469	117
118	278.2	263.5	1.079	.9269	176.6	634.0	457.4	.3535	.1455	118
119	282.3	267.6	1.063	.9408	177.8	634.0	456.2	.3556	.1441	119
120	286.4	271.7	1.047	0.9549	179.0	634.0	455.0	0.3576	1.1427	**120**
121	290.6	275.9	1.032	.9692	180.2	634.0	453.8	.3597	.1414	121
122	294.8	280.1	1.017	.9837	181.4	634.0	452.6	.3618	.1400	122
123	299.1	284.4	1.002	.9983	182.6	634.0	451.4	.3638	.1386	123
124	303.4	288.7	0.987	1.0132	183.9	634.0	450.1	.3659	.1372	124
125	307.8	293.1	0.973	1.028	185.1	634.0	448.9	0.3679	1.1358	**125**

TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.

Pressure (abs.). lbs./in.²	Temp. °F.	Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Heat content. Liquid. Btu./lb.	Heat content. Vapor. Btu./lb.	Latent heat. Btu./lb.	Entropy. Liquid. Btu./lb. °F.	Entropy. Evap. Btu./lb. °F.	Entropy. Vapor. Btu./lb. °F.	Pressure (abs.). lbs./in.²
p	t	V	$1/V$	h	H	L	s	L/T	S	p
5.0	−63.11	49.31	0.02029	−24.5	588.3	612.8	−0.0599	1.5456	1.4857	**5.0**
5.5	−60.27	45.11	.02217	−21.5	589.5	611.0	− .0524	.5301	.4777	5.5
6.0	−57.64	41.59	.02405	−18.7	590.6	609.3	− .0455	.5158	.4703	6.0
6.5	−55.18	38.59	.02591	−16.1	591.6	607.7	− .0390	.5026	.4636	6.5
7.0	−52.88	36.01	.02777	−13.7	592.5	606.2	− .0330	.4904	.4574	7.0
7.5	−50.70	33.77	0.02962	−11.3	593.4	604.7	−0.0274	1.4790	1.4516	**7.5**
8.0	−48.64	31.79	.03146	− 9.2	594.2	603.4	− .0221	.4683	.4462	8.0
8.5	−46.69	30.04	.03329	− 7.1	595.0	602.1	− .0171	.4582	.4411	8.5
9.0	44.83	28.48	.03511	− 5.1	595.7	600.8	− .0123	.4486	.4363	9.0
9.5	−43.05	27.08	.03693	− 3.2	596.4	599.6	− .0077	.4396	.4319	9.5
10.0	−41.34	25.81	0.03874	− 1.4	597.1	598.5	−0.0034	1.4310	1.4276	**10.0**
10.5	−39.71	24.66	.04055	+ 0.3	597.7	597.4	+ .0007	.4228	.4235	10.5
11.0	−38.14	23.61	.04235	2.0	598.3	596.3	.0047	.4149	.4196	11.0
11.5	−36.62	22.65	.04414	3.6	598.9	595.3	.0085	.4074	.4159	11.5
12.0	−35.16	21.77	.04593	5.1	599.4	594.3	.0122	.4002	4124	12.0
12.5	−33.74	20.96	0.04772	6.7	600.0	593.3	0.0157	1.3933	1.4090	**12.5**
13.0	−32.37	20.20	.04950	8.1	600.5	592.4	.0191	.3866	.4057	13.0
13.5	−31.05	19.50	.05128	9.6	601.0	591.4	.0225	.3801	.4026	13.5
14.0	−29.76	18.85	.05305	10.9	601.4	590.5	.0257	.3739	.3996	14.0
14.5	−28.51	18.24	.05482	12.2	601.9	589.7	.0288	.3679	.3967	14.5
15.0	−27.29	17.67	0.05658	13.6	602.4	588.8	0.0318	1.3620	1.3938	**15.0**
15.5	−26.11	17.14	.05834	14.8	602.8	588.0	.0347	.3564	.3911	15.5
16.0	−24.95	16.64	.06010	16.0	603.2	587.2	.0375	.3510	.3885	16.0
16.5	−23.83	16.17	.06186	17.2	603.6	586.4	.0403	.3456	.3859	16.5
17.0	−22.73	15.72	.06361	18.4	604.0	585.6	.0430	.3405	.3835	17.0
17.5	−21.66	15.30	0.06535	19.6	604.4	584.8	0.0456	1.3354	1.3810	**17.5**
18.0	−20.61	14.90	.06710	20.7	604.8	584.1	.0482	.3305	.3787	18.0
18.5	−19.59	14.53	.06884	21.8	605.1	583.3	.0507	.3258	.3765	18.5
19.0	−18.58	14.17	.07058	22.9	605.5	582.6	.0531	.3211	.3742	19.0
19.5	−17.60	13.83	.07232	23.9	605.8	581.9	.0555	.3166	.3721	19.5
20.0	−16.64	13.50	0.07405	25.0	606.2	581.2	0.0578	1.3122	1.3700	**20.0**
20.5	−15.70	13.20	.07578	26.0	606.5	580.5	.0601	.3078	.3679	20.5
21.0	−14.78	12.90	.07751	27.0	606.8	579.8	.0623	.3036	.3659	21.0
21.5	−13.87	12.62	.07924	27.9	607.1	579.2	.0645	.2995	.3640	21.5
22.0	−12.98	12.35	.08096	28.9	607.4	578.5	.0666	.2955	.3621	22.0
22.5	−12.11	12.09	0.08268	29.8	607.7	577.9	0.0687	1.2915	1.3602	**22.5**
23.0	−11.25	11.85	.08440	30.8	608.1	577.3	.0708	.2876	.3584	23.0
23.5	−10.41	11.61	.08612	31.7	608.3	576.6	.0728	.2838	.3566	23.5
24.0	− 9.58	11.39	.08783	32.6	608.6	576.0	.0748	.2801	.3549	24.0
24.5	− 8.76	11.17	.08955	33.5	608.9	575.4	.0768	.2764	.3532	24.5
25.0	− 7.96	10.96	0.09126	34.3	609.1	574.8	0.0787	1.2728	1.3515	**25.0**
25.5	− 7.17	10.76	.09297	35.2	609.4	574.2	.0805	.2693	.3498	25.5
26.0	− 6.39	10.56	.09468	36.0	609.7	573.7	.0824	.2658	.3482	26.0
26.5	− 5.63	10.38	.09638	36.8	609.9	573.1	.0842	.2625	.3467	26.5
27.0	− 4.87	10.20	.09809	37.7	610.2	572.5	.0860	.2591	.3451	27.0
27.5	− 4.13	10.02	0.09979	38.4	610.4	572.0	0.0878	1.2558	1.3436	**27.5**
28.0	− 3.40	9.853	.1015	39.3	610.7	571.4	.0895	.2526	.3421	28.0
28.5	− 2.68	9.691	.1032	40.0	610.9	570.9	.0912	.2494	.3406	28.5
29.0	− 1.97	9.534	.1049	40.8	611.1	570.3	.0929	.2463	.3392	29.0
29.5	− 1.27	9.383	.1066	41.6	611.4	569.8	.0945	.2433	.3378	29.5
30.0	− 0.57	9.236	0.1083	42.3	611.6	569.3	0.0962	1.2402	1.3364	**30.0**

TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.—(*Continued.*)

Pressure (abs.). lbs./in.²	Temp. °F.	Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Heat content. Liquid. Btu./lb.	Heat content. Vapor. Btu./lb.	Latent heat. Btu./lb.	Entropy. Liquid. Btu./lb. °F.	Entropy. Evap. Btu./lb.°F.	Entropy. Vapor. Btu./lb.°F.	Pressure (abs.). lbs./in.²
p	t	V	$1/V$	h	H	L	s	L/T	S	p
30	−0.57	9.236	0.1083	42.3	611.6	569.3	0.0962	1.2402	1.3364	**30**
31	+0.79	8.955	.1117	43.8	612.0	568.2	.0993	.2343	.3336	31
32	2.11	8.693	.1150	45.2	612.4	567.2	.1024	.2286	.3310	32
33	3.40	8.445	.1184	46.6	612.8	566.2	.1055	.2230	.3285	33
34	4.66	8.211	.1218	48.0	613.2	565.2	.1084	.2176	.3260	34
35	5.89	7.991	0.1251	49.3	613.6	564.3	0.1113	1.2123	1.3236	**35**
36	7.09	7.782	.1285	50.6	614.0	563.4	.1141	.2072	.3213	36
37	8.27	7.584	.1319	51.9	614.3	562.4	.1168	.2022	.3190	37
38	9.42	7.396	.1352	53.2	614.7	561.5	.1195	.1973	.3168	38
39	10.55	7.217	.1386	54.4	615.0	560.6	.1221	.1925	.3146	39
40	11.66	7.047	0.1419	55.6	615.4	559.8	0.1246	1.1879	1.3125	**40**
41	12.74	6.885	.1452	56.8	615.7	558.9	.1271	.1833	.3104	41
42	13.81	6.731	.1486	57.9	616.0	558.1	.1296	.1788	.3084	42
43	14.85	6.583	.1519	59.1	616.3	557.2	.1320	.1745	.3065	43
44	15.88	6.442	.1552	60.2	616.6	556.4	.1343	.1703	.3046	44
45	16.88	6.307	0.1586	61.3	616.9	555.6	0.1366	1.1661	1.3027	**45**
46	17.87	6.177	.1619	62.4	617.2	554.8	.1389	.1620	.3009	46
47	18.84	6.053	.1652	63.4	617.4	554.0	.1411	.1580	.2991	47
48	19.80	5.934	.1685	64.5	617.7	553.2	.1433	.1540	.2973	48
49	20.74	5.820	.1718	65.5	618.0	552.5	.1454	.1502	.2956	49
50	21.67	5.710	0.1751	66.5	618.2	551.7	0.1475	1.1464	1.2939	**50**
51	22.58	5.604	.1785	67.5	618.5	551.0	.1496	.1427	.2923	51
52	23.48	5.502	.1818	68.5	618.7	550.2	.1516	.1390	.2906	52
53	24.36	5.404	.1851	69.5	619.0	549.5	.1536	.1354	.2890	53
54	25.23	5.309	.1884	70.4	619.2	548.8	.1556	.1319	.2875	54
55	26.09	5.218	0.1917	71.4	619.4	548.0	0.1575	1.1284	1.2859	**55**
56	26.94	5.129	.1950	72.3	619.7	547.4	.1594	.1250	.2844	56
57	27.77	5.044	.1983	73.3	619.9	546.6	.1613	.1217	.2830	57
58	28.59	4.962	.2015	74.2	620.1	545.9	.1631	.1184	.2815	58
59	29.41	4.882	.2048	75.0	620.3	545.3	.1650	.1151	.2801	59
60	30.21	4.805	0.2081	75.9	620.5	544.6	0.1668	1.1119	1.2787	**60**
61	31.00	4.730	.2114	76.8	620.7	543.9	.1686	.1088	.2773	61
62	31.78	4.658	.2147	77.7	620.9	543.2	.1703	.1056	.2759	62
63	32.55	4.588	.2180	78.5	621.1	542.6	.1720	.1026	.2746	63
64	33.31	4.519	.2213	79.4	621.3	541.9	.1737	.0996	.2733	64
65	34.06	4.453	0.2245	80.2	621.5	541.3	0.1754	1.0966	1.2720	**65**
66	34.81	4.389	.2278	81.0	621.7	540.7	.1770	.0937	.2707	66
67	35.54	4.327	.2311	81.8	621.9	540.1	.1787	.0907	.2694	67
68	36.27	4.267	.2344	82.6	622.0	539.4	.1803	.0879	.2682	68
69	36.99	4.208	.2377	83.4	622.2	538.8	.1819	.0851	.2670	69
70	37.70	4.151	0.2409	84.2	622.4	538.2	0.1835	1.0823	1.2658	**70**
71	38.40	4.095	.2442	85.0	622.6	537.6	.1850	.0795	.2645	71
72	39.09	4.041	.2475	85.8	622.8	537.0	.1866	.0768	.2634	72
73	39.78	3.988	.2507	86.5	622.9	536.4	.1881	.0741	.2622	73
74	40.46	3.937	.2540	87.3	623.1	535.8	.1896	.0715	.2611	74
75	41.13	3.887	0.2573	88.0	623.2	535.2	0.1910	1.0689	1.2599	**75**
76	41.80	3.838	.2606	88.8	623.4	534.6	.1925	.0663	.2588	76
77	42.46	3.790	.2638	89.5	623.5	534.0	.1940	.0637	.2577	77
78	43.11	3.744	.2671	90.2	623.7	533.5	.1954	.0612	.2566	78
79	43.76	3.699	.2704	90.9	623.8	532.9	.1968	.0587	.2555	79
80	44.40	3.655	0.2736	91.7	624.0	532.3	0.1982	1.0563	1.2545	**80**

TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.—(*Continued.*)

Pressure (abs.). lbs./in.²	Temp. °F.	Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Heat content. Liquid. Btu./lb.	Heat content. Vapor. Btu./lb.	Latent heat. Btu./lb.	Entropy. Liquid. Btu./lb. °F.	Entropy. Evap. Btu./lb. °F.	Entropy. Vapor. Btu./lb. °F.	Pressure (abs.). lbs./in.²
p	t	V	$1/V$	h	H	L	s	L/T	S	p
80	44.40	3.655	0.2736	91.7	624.0	532.3	0.1982	1.0563	1.2545	**80**
81	45.03	3.612	.2769	92.4	624.1	531.7	.1996	.0538	.2534	81
82	45.66	3.570	.2801	93.1	624.3	531.2	.2010	.0514	.2524	82
83	46.28	3.528	.2834	93.8	624.4	530.6	.2024	.0490	.2514	83
84	46.89	3.488	.2867	94.5	624.6	530.1	.2037	.0467	.2504	84
85	47.50	3.449	0.2899	95.1	624.7	529.6	0.2051	1.0443	1.2494	**85**
86	48.11	3.411	.2932	95.8	624.8	529.0	.2064	.0420	.2484	86
87	48.71	3.373	.2964	96.5	625.0	528.5	.2077	.0397	.2474	87
88	49.30	3 337	.2997	97.2	625.1	527.9	.2090	.0375	.2465	88
89	49.89	3.301	.3030	97.8	625.2	527.4	.2103	.0352	.2455	89
90	50.47	3.266	0.3062	98.4	625.3	526.9	0.2115	1.0330	1.2445	**90**
91	51.05	3.231	.3095	99.1	625.5	526.4	.2128	.0308	.2436	91
92	51.62	3.198	.3127	99.8	625.6	525.8	.2141	.0286	.2427	92
93	52.19	3.165	.3160	100.4	625.7	525.3	.2153	.0265	.2418	93
94	52.76	3.132	.3192	101.0	625.8	524.8	.2165	.0243	.2408	94
95	53.32	3.101	0.3225	101.6	625.9	524.3	0.2177	1.0222	1.2399	**95**
96	53.87	3.070	.3258	102.3	626.1	523.8	.2190	.0201	.2391	96
97	54.42	3.039	.3290	102.9	626.2	523.3	.2201	.0181	.2382	97
98	54.97	3.010	.3323	103.5	626.3	522.8	.2213	.0160	.2373	98
99	55.51	2.980	.3355	104.1	626.4	522.3	.2225	.0140	.2365	99
100	56.05	2.952	0.3388	104.7	626.5	521.8	0.2237	1.0119	1.2356	**100**
102	57.11	2.896	.3453	105.9	626.7	520.8	.2260	.0079	.2339	102
104	58.16	2.843	.3518	107.1	626.9	519.8	.2282	.0041	.2323	104
106	59.19	2.791	.3583	108.3	627.1	518.8	.2305	1.0002	.2307	106
108	60.21	2.741	.3648	109.4	627.3	517.9	.2327	0.9964	.2291	108
110	61.21	2.693	0.3713	110.5	627.5	517.0	0.2348	0.9927	1.2275	**110**
112	62.20	2.647	.3778	111.7	627.7	516.0	.2369	.9890	.2259	112
114	63.17	2.602	.3843	112.8	627.9	515.1	.2390	.9854	.2244	114
116	64.13	2.559	.3909	113.9	628.1	514.2	.2411	.9819	.2230	116
118	65.08	2.517	.3974	114.9	628.2	513.3	.2431	.9784	.2215	118
120	66.02	2.476	0.4039	116.0	628.4	512.4	0.2452	0.9749	1.2201	**120**
122	66.94	2.437	.4104	117.1	628.6	511.5	.2471	.9715	.2186	122
124	67.86	2.399	.4169	118.1	628.7	510.6	.2491	.9682	.2173	124
126	68.76	2.362	.4234	119.1	628.9	509.8	.2510	.9649	.2159	126
128	69.65	2.326	.4299	120.1	629.0	508.9	.2529	.9616	.2145	128
130	70.53	2.291	0.4364	121.1	629.2	508.1	0.2548	0.9584	1.2132	**130**
132	71.40	2.258	.4429	122.1	629.3	507.2	.2567	.9552	.2119	132
134	72.26	2.225	.4494	123.1	629.5	506.4	.2585	.9521	.2106	134
136	73.11	2.193	.4559	124.1	629.6	505.5	.2603	.9490	.2093	136
138	73.95	2.162	.4624	125.1	629.8	504.7	.2621	.9460	.2081	138
140	74.79	2.132	0.4690	126.0	629.9	503.9	0.2638	0.9430	1.2068	**140**
142	75.61	2.103	.4755	126.9	630.0	503.1	.2656	.9400	.2056	142
144	76.42	2.075	.4820	127.9	630.2	502.3	.2673	.9371	.2044	144
146	77.23	2.047	.4885	128.8	630.3	501.5	.2690	.9342	.2032	146
148	78.03	2.020	.4951	129.7	630.4	500.7	.2707	.9313	.2020	148
150	78.81	1.994	0.5016	130.6	630.5	499.9	0.2724	0.9285	1.2009	**150**

TABLE XVIII.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SATURATED AMMONIA: ABSOLUTE PRESSURE TABLE.—(*Continued.*)

Pressure (abs.). lbs./in.²	Temp. °F.	Volume vapor. ft.³/lb.	Density vapor. lbs./ft.³	Heat content.		Latent heat. Btu./lb.	Entropy.			Pressure (abs.). lbs./in.²
				Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb. °F.	Evap. Btu./lb. °F.	Vapor. Btu./lb. °F.	
p	t	V	$1/V$	h	H	L	s	L/T	S	p
150	78.81	1.994	0.5016	130.6	630.5	499.9	0.2724	0.9285	1.2009	**150**
152	79.60	1.968	.5081	131.5	630.6	499.1	.2740	.9257	.1997	152
154	80.37	1.943	.5147	132.4	630.7	498.3	.2756	.9229	.1985	154
156	81.13	1.919	.5212	133.3	630.9	497.6	.2772	.9202	.1974	156
158	81.89	1.895	.5277	134.2	631.0	496.8	.2788	.9175	.1963	158
160	82.64	1.872	0.5343	135.0	631.1	496.1	0.2804	0.9148	1.1952	**160**
162	83.39	1.849	.5408	135.9	631.2	495.3	.2820	.9122	.1942	162
164	84.12	1.827	.5473	136.8	631.3	494.5	.2835	.9096	.1931	164
166	84.85	1.805	.5539	137.6	631.4	493.8	.2850	.9070	.1920	166
168	85.57	1.784	.5604	138.4	631.5	493.1	.2866	.9044	.1910	168
170	86.29	1.764	0.5670	139.3	631.6	492.3	0.2881	0.9019	1.1900	**170**
172	87.00	1.744	.5735	140.1	631.7	491.6	.2895	.8994	.1889	172
174	87.71	1.724	.5801	140.9	631.7	490.8	.2910	.8969	.1879	174
176	88.40	1.705	.5866	141.7	631.8	490.1	.2925	.8944	.1869	176
178	89.10	1.686	.5932	142.5	631.9	489.4	.2939	.8920	.1859	178
180	89.78	1.667	0.5998	143.3	632.0	488.7	0.2954	0.8896	1.1850	**180**
182	90.46	1.649	.6063	144.1	632.1	488.0	.2968	.8872	.1840	182
184	91.14	1.632	.6129	144.8	632.1	487.3	.2982	.8848	.1830	184
186	91.80	1.614	.6195	145.6	632.2	486.6	.2996	.8825	.1821	186
188	92.47	1.597	.6261	146.4	632.3	485.9	.3010	.8801	.1811	188
190	93.13	1.581	0.6326	147.2	632.4	485.2	0.3024	0.8778	1.1802	**190**
192	93.78	1.564	.6392	147.9	632.4	484.5	.3037	.8755	.1792	192
194	94.43	1.548	.6458	148.7	632.5	483.8	.3050	.8733	.1783	194
196	95.07	1.533	.6524	149.5	632.6	483.1	.3064	.8710	.1774	196
198	95.71	1.517	.6590	150.2	632.6	482.4	.3077	.8688	.1765	198
200	96.34	1.502	0.6656	150.9	632.7	481.8	0.3090	0.8666	1.1756	**200**
205	97.90	1.466	.6821	152.7	632.8	480.1	.3122	.8612	.1734	205
210	99.43	1.431	.6986	154.6	633.0	478.4	.3154	.8559	.1713	210
215	100.94	1.398	.7152	156.3	633.1	476.8	.3185	.8507	.1692	215
220	102.42	1.367	.7318	158.0	633.2	475.2	.3216	.8455	.1671	220
225	103.87	1.336	0.7484	159.7	633.3	473.6	0.3246	0.8405	1.1651	**225**
230	105.30	1.307	.7650	161.4	633.4	472.0	.3275	.8356	.1631	230
235	106.71	1.279	.7817	163.1	633.5	470.4	.3304	.8307	.1611	235
240	108.09	1.253	.7984	164.7	633.6	468.9	.3332	.8260	.1592	240
245	109.46	1.227	.8151	166.4	633.7	467.3	.3360	.8213	.1573	245
250	110.80	1.202	0.8319	168.0	633.8	465.8	0.3388	0.8167	1.1555	**250**
255	112.12	1.178	.8487	169.5	633.8	464.3	.3415	.8121	.1536	255
260	113.42	1.155	.8655	171.1	633.9	462.8	.3441	.8077	.1518	260
265	114.71	1.133	.8824	172.6	633.9	461.3	.3468	.8033	.1501	265
270	115.97	1.112	.8993	174.1	633.9	459.8	.3494	.7989	.1483	270
275	117.22	1.091	0.9162	175.6	634.0	458.4	0.3519	0.7947	1.1466	**275**
280	118.45	1.072	.9332	177.1	634.0	456.9	.3545	.7904	.1449	280
285	119.66	1.052	.9502	178.6	634.0	455.4	.3569	.7863	.1432	285
290	120.86	1.034	.9672	180.0	634.0	454.0	.3594	.7821	.1415	290
295	122.05	1.016	.9843	181.5	634.0	452.5	.3618	.7781	.1399	295
300	123.21	0.999	1.0015	182.9	634.0	451.1	0.3642	0.7741	1.1383	**300**

TABLE XIX.—BUREAU OF STANDARDS TABLE OF PROPERTIES OF LIQUID AMMONIA.

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1924

Temp °F t	(At Saturation) Pressure (Abs.) lb./in.² p	Pressure (Gage) lb./in.² $g\,p$	Volume ft.³/lb. v	Density lb./ft.³ $1/v$	Specific Heat Btu/lb.-°F c	Heat Content Above −40° Btu/lb. h	Latent Heat Btu/lb. L	Latent Heat of Pressure Variation $\frac{\text{Btu/lb.}}{\text{lb./in.}^2}$ l	Variation of h with p (t Constant) $\frac{\text{Btu/lb.}}{\text{lb./in.}^2}$ $-\frac{100}{v}\left(\frac{\delta h}{\delta p}\right)_t$	Compressibility % Change in v $\frac{}{\text{lb./in.}^2}$ $-\frac{100}{v}\left(\frac{\delta v}{\delta p}\right)_t$	Temp °F t
Triple		28.1*	0.01961	51.00	.....	.....	.....	(Properties of solid ammonia)			−107.86
point	0.88	28.1*	.02182	45.83	.....	.....	.....				−107.86
−100	1.24	27.4*	0.02197	45.52	1.040†	−63.0†	633†				**−100**
−95	1.52	26.8*	.02207	45.32	1.042†	−57.8†	631†				−95
−90	1.86	26.1*	.02216	45.12	1.043†	−52.6†	628†				−90
−85	2.27	25.3*	.02226	44.92	1.045†	−47.4†	625†				−85
−80	2.74	24.3*	.02236	44.72	1.046†	−42.2†	622†				−80
−75	3.29	23.2*	0.02246	44.52	1.048†	−36.9†	619†				**−75**
−70	3.94	21.9*	.02256	44.32	1.050†	−31.7†	616†				−70
−65	4.69	20.4*	.02267	44.11	1.052†	−26.4†	613†				−65
−60	5.55	18.6*	.02278	43.91	1.054	−21.18	610.8	−0.0016	0.0026	0.00044	−60
−55	6.54	16.6*	.02288	43.70	1.056	−15.90	607.5	−.0016	.0026	.00045	−55
−50	7.67	14.3*	0.02299	43.49	1.058	−10.61	604.3	−0.0017	0.0026	0.00046	**−50**
−45	8.95	11.7*	.02310	43.28	1.060	−5.31	600.9	−.0017	.0026	.00047	−45
−40	10.41	8.7*	.02322	43.08	1.062	**0.00**	597.6	−.0018	.0025	.00048	−40
−35	12.05	5.4*	.02333	42.86	1.064	+5.32	594.2	−.0018	.0025	.00050	−35
−30	13.90	1.6*	.02345	42.65	1.066	10.66	590.7	−.0019	.0025	.00051	−30
−25	15.98	1.3	0.02357	42.44	1.068	16.00	587.2	−0.0019	0.0024	0.00052	**−25**
−20	18.30	3.6	.02369	42.22	1.070	21.36	583.6	−.0020	.0024	.00054	−20
−15	20.88	6.2	.02381	42.00	1.073	26.73	580.0	−.0020	.0024	.00055	−15
−10	23.74	9.0	.02393	41.78	1.075	32.11	576.4	−.0021	.0023	.00057	−10
−5	26.92	12.2	.02406	41.56	1.078	37.51	572.6	−.0022	.0023	.00058	−5
0	30.42	15.7	0.02419	41.34	1.080	42.92	568.9	−0.0022	0.0022	0.00060	**0**
5‡	**34.27**	**19.6**	**.02432**	**41.11**	**1.083**	**48.35**	**565.0**	**−.0023**	**.0022**	**.00062**	**5**
10	38.51	23.8	.02446	40.89	1.085	53.79	561.1	−.0024	.0021	.00064	10
15	43.14	28.4	.02460	40.66	1.088	59.24	557.1	−.0025	.0021	.00066	15
20	48.21	33.5	.02474	40.43	1.091	64.71	553.1	−.0025	.0020	.00068	20
25	53.73	39.0	0.02488	40.20	1.094	70.20	548.9	−0.0026	0.0020	0.00070	**25**
30	59.74	45.0	.02503	39.96	1.097	75.71	544.8	−.0027	.0019	.00073	30
35	66.26	51.6	.02518	39.72	1.100	81.23	540.5	−.0028	.0019	.00075	35
40	73.32	58.6	.02533	39.49	1.104	86.77	536.2	−.0029	.0018	.00078	40
45	80.96	66.3	.02548	39.24	1.108	92.34	531.8	−.0030	.0017	.00081	45
50	89.19	74.5	0.02564	39.00	1.112	97.93	527.3	−0.0031	0.0017	0.00084	**50**
55	98.06	83.4	.02581	38.75	1.116	103.54	522.8	−.0032	.0016	.00088	55
60	107.6	92.9	.02597	38.50	1.120	109.18	518.1	−.0033	.0015	.00091	60
65	117.8	103.1	.02614	38.25	1.125	114.85	513.4	−.0034	.0014	.00095	65
70	128.8	114.1	.02632	38.00	1.129	120.54	508.6	−.0035	.0013	.00100	70
75	140.5	125.8	0.02650	37.74	1.133	126.25	503.7	−0.0037	0.0012	0.00104	**75**
80	153.0	138.3	.02668	37.48	1.138	131.99	498.7	−.0038	.0011	.00109	80
85	166.4	151.7	.02687	37.21	1.142	137.75	493.6	−.0040	.0010	.00114	85
86‡	**169.2**	**154.5**	**.02673**	**37.16**	**1.143**	**127.40**	**492.6**	**.0040**	**.0010**	**.00115**	**86**
90	180.6	165.9	.02707	36.95	1.147	143.54	488.5	−.0041	.0009	.00120	90
95	195.8	181.1	.02727	36.67	1.151	149.36	483.2	−.0043	.0008	.00126	95
100	211.9	197.2	0.02747	36.40	1.156	155.21	477.8	−0.0045	0.0006	0.00133	**100**
105	228.9	214.2	.02769	36.12	1.162	161.09	472.3	−.0047	.0005	.00141	105
110	247.0	232.3	.02790	35.84	1.168	167.01	466.7	−.0049	.0003	.00149	110
115	266.2	251.5	.02813	35.55	1.176	172.97	460.9	−.0051	.0001	.00158	115
120	286.4	271.7	.02836	35.26	1.183	178.98	455.0	−.0053	.0000	.00167	120
125	307.8	293.1	0.02860	34.96	1.189†	185†	449†				**125**
130	330.3	315.6	.02885	34.66	1.197†	191†	443†				130
135	354.1	339.4	.02911	34.35	1.205†	197†	436†				135
140	379.1	364.4	.02938	34.04	1.213†	203†	430†				140
145	405.5	390.8	.02966	33.72	1.222†	210†	423†				145
150	433.2	418.5	0.02995	33.39	1.23†	216†	416†				**150**
155	462.3	447.6	.03025	33.06	1.24†	222†	409†				155
160	492.8	478.1	.03056	32.72	1.25†	229†	401†				160
165	524.8	510.1	.03089	32.37	1.26†	235†	394†				165
170	558.4	543.7	.03124	32.01	1.27†	241†	386†				170
Critical	1,657.	1,642.3	.0686	14.6		433†	0				**271.4**

†These figures were calculated from empirical equations given in Bureau of Standards Scientific Papers Nos. 313 and 315, and represent values obtained by extrapolation beyond the range covered in the experimental work.

NOTES—At the critical temperature of 271.4° F. (Cardoso and Gil) the pressure is 1,657 lbs., the volume .0686 cubic feet, the density 14.6 lbs., and the heat content 433 Btu.

Values for gage pressure (g p), absolute pressure (p), liquid volume (v), and density (1/v), heat of the liquid (h) and latent heat (L), are given for single Fahrenheit degrees in Table 2.

*Inches of mercury, at 32°F., below one standard atmosphere (29.92 in. = 14.696 lbs. abs.)
‡Standard ton temperatures.

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SUPERHEATED AMMONIA VAPORS

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

Abs. Pressure 5 lb./in.^{2} — Gage Pressure 19.7* (Sat'n Temp. −63.11° F.)

Tem. °F. *t*	Volume ft.^{3}/lb. *V*	Heat Content Btu./lb. *H*	Entropy Btu./lb. °F. *S*
(at sat'n)	(49.31)	(588.3)	(1.4857)
−50	51.05	595.2	1.5025
−40	52.36	600.3	1.5149
−30	53.67	605.4	1.5269
−20	54.97	610.4	1.5385
−10	56.26	615.4	1.5498
0	57.55	620.4	1.5608
10	58.84	625.4	1.5716
20	60.12	630.4	1.5821
30	61.41	635.4	1.5925
40	62.69	640.4	1.6026
50	63.96	645.5	1.6125
60	65.24	650.5	1.6223
70	66.51	655.5	1.6319
80	67.79	660.6	1.6413
90	69.06	665.6	1.6506
100	70.33	670.7	1.6598
110	71.60	675.8	1.6689
120	72.87	680.9	1.6778
130	74.14	686.1	1.6865
140	75.41	691.2	1.6952
150	76.68	696.4	1.7038
160	77.95	701.6	1.7122
170	79.21	706.8	1.7206
180	80.48	712.1	1.7289

Abs. Pressure 10 lb./in.^{2} — Gage Pressure 9.6* (Sat'n Temp.—41.34° F.)

Tem. °F. *t*	Volume ft.^{3}/lb. *V*	Heat Content Btu./lb. *H*	Entropy Btu./lb. °F. *S*
(at sat'n)	(25.81)	(597.1)	(1.4276)
−40	25.90	597.8	1.4293
−30	26.58	603.2	1.4420
−20	27.26	608.5	1.4542
−10	27.92	613.7	1.4659
0	28.58	618.9	1.4773
10	29.24	624.0	1.4884
20	29.90	629.1	1.4992
30	30.55	634.2	1.5097
40	31.20	639.3	1.5200
50	31.85	644.4	1.5301
60	32.49	649.5	1.5400
70	33.14	654.6	1.5497
80	33.78	659.7	1.5593
90	34.42	664.8	1.5687
100	35.07	670.0	1.5779
110	35.71	675.1	1.5870
120	36.35	680.3	1.5960
130	36.99	685.4	1.6049
140	37.62	690.6	1.6136
150	38.26	695.8	1.6222
160	38.90	701.1	1.6307
170	39.54	706.3	1.6391
180	40.17	711.6	1.6474
190	40.81	716.9	1.6556
200	41.45	722.2	1.6637

Abs. Pressure 15 lb./in.^{2} — Gage Press. 0.3 lb./in.^{2} (Sat'n Temp.—27.29° F.)

Tem. °F. *t*	Volume ft.^{3}/lb. *V*	Heat Content Btu./lb. *H*	Entropy Btu./lb. °F. *S*
(at sat'n)	(17.67)	(602.4)	(1.3938)
−30	......	......	......
−20	18.01	606.4	1.4031
−10	18.47	611.9	1.4154
0	18.92	617.2	1.4272
10	19.37	622.5	1.4386
20	19.82	627.8	1.4497
30	20.26	633.0	1.4604
40	20.70	638.2	1.4709
50	21.14	643.4	1.4812
60	21.58	648.5	1.4912
70	22.01	653.7	1.5011
80	22.44	658.9	1.5108
90	22.88	664.0	1.5203
100	23.31	669.2	1.5296
110	23.74	674.4	1.5388
120	24.17	679.6	1.5478
130	24.60	684.8	1.5567
140	25.03	690.0	1.5655
150	25.46	695.3	1.5742
160	25.88	700.5	1.5827
170	26.31	705.8	1.5911
180	26.74	711.1	1.5995
190	27.16	716.4	1.6077
200	27.59	721.7	1.6158
210	28.02	727.0	1.6239
220	28.44	732.4	1.6318
230	28.88	737.8	1.6397
240	29.29	743.2	1.6475
250	29.71	748.6	1.6552

Abs. Pressure 20 lb./in.^{2} — Gage Press. 5.3 lb./in.^{2} (Sat'n Temp.—16.64°F.)

Tem. °F.	V	H	S
(at sat'n)	(13.50)	(606.2)	(1.3700)
−20	......	......	......
−10	13.74	610.0	1.3784
0	14.09	615.5	1.3907
10	14.44	621.0	1.4025
20	14.78	626.4	1.4138
30	15.11	631.7	1.4248
40	15.45	637.0	1.4356
50	15.78	642.3	1.4460
60	16.12	647.5	1.4562
70	16.45	652.8	1.4662
80	16.78	658.0	1.4760
90	17.10	663.2	1.4856
100	17.43	668.5	1.4950
110	17.76	673.7	1.5042
120	18.08	678.9	1.5133
130	18.41	684.2	1.5223
140	18.73	689.4	1.5312
150	19.05	694.7	1.5399
160	19.37	700.0	1.5485
170	19.70	705.3	1.5569
180	20.02	710.6	1.5653
190	20.34	715.9	1.5736
200	20.66	721.2	1.5817
210	20.98	726.6	1.5898
220	21.30	732.0	1.5978
230	21.62	737.4	1.6057
240	21.94	742.8	1.6135
250	22.26	748.3	1.6212

Abs. Pressure 25 lb./in.^{2} — Gage Press. 10.3 lb./in.^{2} (Sat'n Temp.—7.96° F.)

Tem. °F.	V	H	S
(at sat'n)	(10.96)	(609.1)	(1.3515)
0	11.19	613.8	1.3616
10	11.47	619.4	1.3738
20	11.75	625.0	1.3855
30	12.03	630.4	1.3967
40	12.30	635.8	1.4077
50	12.57	641.2	1.4183
60	12.84	646.5	1.4287
70	13.11	651.8	1.4388
80	13.37	657.1	1.4487
90	13.64	662.4	1.4584
100	13.90	667.7	1.4679
110	14.17	673.0	1.4772
120	14.43	678.2	1.4864
130	14.69	683.5	1.4954
140	14.95	688.8	1.5043
150	15.21	694.1	1.5131
160	15.47	699.4	1.5217
170	15.73	704.7	1.5303
180	15.99	710.1	1.5387
190	16.25	715.4	1.5470
200	16.50	720.8	1.5552
210	16.76	726.2	1.5633
220	17.02	731.6	1.5713
230	17.27	737.0	1.5792
240	17.53	742.5	1.5870
250	17.79	747.9	1.5948
260	18.04	753.4	1.6025
270	18.30	758.9	1.6101

Abs. Pressure 30 lb./in.^{2} — Gage Press. 15.3 lb./in.^{2} (Sat'n Temp. −0.57° F.)

Tem. °F.	V	H	S
(at sat'n)	(9.236)	(611.6)	(1.3364)
0	9.250	611.9	1.3371
10	9.492	617.8	1.3497
20	9.731	623.5	1.3618
30	9.966	629.1	1.3733
40	10.20	634.6	1.3845
50	10.43	640.1	1.3953
60	10.65	645.5	1.4059
70	10.88	650.9	1.4161
80	11.10	656.2	1.4261
90	11.33	661.6	1.4359
100	11.55	666.9	1.4456
110	11.77	672.2	1.4550
120	11.99	677.5	1.4642
130	12.21	682.9	1.4733
140	12.43	688.2	1.4823
150	12.65	693.5	1.4911
160	12.87	698.8	1.4998
170	13.08	704.2	1.5083
180	13.30	709.6	1.5168
190	13.52	714.9	1.5251
200	13.73	720.3	1.5334
210	13.95	725.7	1.5415
220	14.16	731.1	1.5495
230	14.38	736.6	1.5575
240	14.59	742.0	1.5653
250	14.81	747.5	1.5732
260	15.02	753.0	1.5808
270	15.23	758.5	1.5884
280	15.45	764.1	1.5960

NOTE:—"V" is Volume of Superheated Vapor, ft.^{3}/lb.; "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

*Inches of mercury at 32° F. below one standard atmosphere (29.92 in. = 14,696 lbs. abs.)

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SUPERHEATED AMMONIA VAPORS—*Continued*

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

Tem. °F.	Abs. Pressure 35 lb./in.² Gage Press. 20.3 lb./in.² (Sat'n Temp. 5.89° F.) Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb. °F.
t	*V*	*H*	*S*
(at sat'n)	(7.991)	(613.6)	(1.3236)
10	8.078	616.1	1.3289
20	8.287	622.0	1.3413
30	8.495	627.7	1.3532
40	8.695	633.4	1.3646
50	8.895	638.9	1.3756
60	9.093	644.4	1.3863
70	9.289	649.9	1.3967
80	9.484	655.3	1.4069
90	9.677	660.7	1.4168
100	9.869	666.1	1.4265
110	10.06	671.5	1.4360
120	10.25	676.8	1.4453
130	10.44	682.2	1.4545
140	10.63	687.6	1.4635
150	10.82	692.9	1.4724
160	11.00	698.3	1.4811
170	11.19	703.7	1.4897
180	11.38	709.1	1.4982
190	11.56	714.5	1.5066
200	11.75	719.9	1.5148
210	11.94	725.3	1.5230
220	12.12	730.7	1.5311
230	12.31	736.2	1.5390
240	12.49	741.7	1.5469
250	12.68	747.2	1.5547
260	12.86	752.7	1.5624
270	13.04	758.2	1.5701
280	13.23	763.7	1.5776

Tem. °F.	Abs. Pressure 40 lb./in.² Gage Press. 25.3 lb./in.² (Sat'n Temp. 11.66° F.) Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb. °F.
t	*V*	*H*	*S*
(at sat'n)	(7.047)	(615.4)	(1.3125)
10	....	....	....
20	7.203	620.4	1.3231
30	7.387	626.3	1.3353
40	7.568	632.1	1.3470
50	7.746	637.8	1.3583
60	7.922	643.4	1.3692
70	8.096	648.9	1.3797
80	8.268	654.4	1.3900
90	8.439	659.9	1.4000
100	8.609	665.3	1.4098
110	8.777	670.7	1.4191
120	8.945	676.1	1.4288
130	9.112	681.5	1.4381
140	9.278	686.9	1.4471
150	9.444	692.3	1.4561
160	9.609	697.7	1.4648
170	9.774	703.1	1.4735
180	9.938	708.5	1.4820
190	10.10	714.0	1.4904
200	10.27	719.4	1.4987
210	10.43	724.9	1.5069
220	10.59	730.3	1.5150
230	10.75	735.8	1.5230
240	10.92	741.3	1.5309
250	11.08	746.8	1.5387
260	11.24	752.3	1.5465
270	11.40	757.8	1.5541
280	11.56	763.4	1.5617

Tem. °F.	Abs. Pressure 50 lb./in.² Gage Press. 35.3 lb./in.² (Sat'n Temp. 21.67 °F.) Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb. °F.
t	*V*	*H*	*S*
(at sat'n)	(5.710)	(618.2)	(1.2939)
30	5.838	623.4	1.3046
40	5.988	629.5	1.3169
50	6.135	635.4	1.3286
60	6.280	641.2	1.3399
70	6.423	646.9	1.3508
80	6.564	652.6	1.3613
90	6.704	658.2	1.3716
100	6.843	663.7	1.3816
110	6.980	669.2	1.3914
120	7.117	674.7	1.4009
130	7.252	680.2	1.4103
140	7.387	685.7	1.4195
150	7.521	691.1	1.4286
160	7.655	696.6	1.4374
170	7.788	702.1	1.4462
180	7.921	707.5	1.4548
190	8.053	713.0	1.4633
200	8.185	718.5	1.4716
210	8.317	724.0	1.4799
220	8.448	729.4	1.4880
230	8.579	735.0	1.4961
240	8.710	740.5	1.5040
250	8.840	746.0	1.5119
260	8.970	751.6	1.5197
270	9.100	757.2	1.5274
280	9.230	762.7	1.5350
290	9.360	768.4	1.5425
300	9.489	774.0	1.5500
310	9.618	779.6	1.5574

Tem. °F.	Abs. Pressure 60 lb./in.² Gage Press. 45.3 lb./in.² (Sat'n Temp. 30.21° F.)		
(at sat'n)	(4.805)	(620.5)	(1.2787)
30	....	....	....
40	4.933	626.8	1.2913
50	5.060	632.9	1.3035
60	5.184	639.0	1.3152
70	5.307	644.9	1.3265
80	5.428	650.7	1.3373
90	5.547	656.4	1.3479
100	5.665	662.1	1.3581
110	5.781	667.7	1.3681
120	5.897	673.3	1.3778
130	6.012	678.9	1.3873
140	6.126	684.4	1.3966
150	6.239	689.9	1.4058
160	6.352	695.5	1.4148
170	6.464	701.0	1.4236
180	6.576	706.5	1.4323
190	6.687	712.0	1.4409
200	6.798	717.5	1.4493
210	6.909	723.1	1.4576
220	7.019	728.6	1.4658
230	7.129	734.1	1.4739
240	7.238	739.7	1.4819
250	7.348	745.3	1.4898
260	7.457	750.9	1.4976
270	7.566	756.5	1.5053
280	7.675	762.1	1.5130
290	7.783	767.7	1.5206
300	7.892	773.3	1.5281
310	8.000	779.0	1.5355

Tem. °F.	Abs. Pressure 70 lb./in.² Gage Press. 55.3 lb./in.² (Sat'n Temp. 37.70° F.)		
(at sat'n)	(4.151)	(622.4)	(1.2658)
40	4.177	623.9	1.2688
50	4.290	630.4	1.2816
60	4.401	636.6	1.2937
70	4.509	642.7	1.3054
80	4.615	648.7	1.3166
90	4.719	654.6	1.3274
100	4.822	660.4	1.3378
110	4.924	666.1	1.3480
120	5.025	671.8	1.3579
130	5.125	677.5	1.3676
140	5.224	683.1	1.3770
150	5.323	688.7	1.3863
160	5.420	694.3	1.3954
170	5.518	699.9	1.4043
180	5.615	705.5	1.4131
190	5.711	711.0	1.421
200	5.807	716.6	1.4302
210	5.902	722.2	1.4386
220	5.998	727.7	1.4469
230	6.093	733.3	1.4550
240	6.187	738.9	1.4631
250	6.281	744.5	1.4711
260	6.376	750.1	1.4789
270	6.470	755.8	1.4866
280	6.563	761.4	1.4943
290	6.657	767.1	1.5019
300	6.750	772.7	1.5095
310	6.844	778.4	1.5169
320	6.937	784.1	1.5243

Tem. °F.	Abs. Pressure 80 lb./in.² Gage Press. 65.3 lb./in.² (Sat'n Temp. 44.40° F.)		
(at sat'n)	(3.655)	(624.0)	(1.2345)
50	3.712	627.7	1.2619
60	3.812	634.3	1.2745
70	3.909	640.6	1.2866
80	4.005	646.7	1.2981
90	4.098	652.8	1.3092
100	4.190	658.7	1.3199
110	4.281	664.6	1.3303
120	4.371	670.4	1.3404
130	4.460	676.1	1.3502
140	4.548	681.8	1.3598
150	4.635	687.5	1.3692
160	4.722	693.2	1.3784
170	4.808	698.8	1.3874
180	4.893	704.4	1.3963
190	4.978	710.0	1.4050
200	5.063	715.6	1.4136
210	5.147	721.3	1.4220
220	5.231	726.9	1.4304
230	5.315	732.5	1.4386
240	5.398	738.1	1.4467
250	5.482	743.8	1.4547
260	5.565	749.4	1.4626
270	5.647	755.1	1.4704
280	5.730	760.7	1.4781
290	5.812	766.4	1.4857
300	5.894	772.1	1.4933
310	5.976	777.8	1.5008
320	6.058	783.5	1.5081

NOTE:—"V" is Volume of Superheated Vapor, ft.³/lb.; "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SUPERHEATED AMMONIA VAPORS—*Continued*

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

Tem. °F. t	Abs. Pressure **90** lb./in.² Gage Press. **75.3** lb./in.² (Sat'n Temp. 50.47° F.) Volume ft.³/lb. V	Heat Content Btu./lb. H	Entropy Btu./lb. °F. S
(at sat'n)	*(3.266)*	*(625.3)*	*(1.2445)*
50	......	......	......
60	3.353	631.8	1.2571
70	3.442	638.3	1.2695
80	3.529	644.7	1.2814
90	3.614	650.9	1.2928
100	3.698	657.0	1.3038
110	3.780	663.0	1.3144
120	3.862	668.9	1.3247
130	3.942	674.7	1.3347
140	4.021	680.5	1.3444
150	4.100	686.3	1.3539
160	4.178	692.0	1.3633
170	4.255	697.7	1.3724
180	4.332	703.4	1.3813
190	4.408	709.0	1.3901
200	4.484	714.7	1.3988
210	4.560	720.4	1.4073
220	4.635	726.0	1.4157
230	4.710	731.7	1.4239
240	4.785	737.3	1.4321
250	4.859	743.0	1.4401
260	4.933	748.7	1.4481
270	5.007	754.4	1.4559
280	5.081	760.0	1.4637
290	5.155	765.8	1.4713
300	5.228	771.5	1.4789
310	5.301	777.2	1.4864
320	5.374	783.0	1.4938

Tem. °F. t	Abs. Pressure **100** lb./in.² Gage Press. **85.3** lb./in.² (Sat'n Temp. 56.05° F.) Volume ft.³/lb. V	Heat Content Btu./lb. H	Entropy Btu./lb. °F. S
(at sat'n)	*(2.952)*	*(626.5)*	*(1.2356)*
60	2.985	629.3	1.2409
70	3.068	636.0	1.2539
80	3.149	642.6	1.2661
90	3.227	649.0	1.2778
100	3.304	655.2	1.2891
110	3.380	661.3	1.2999
120	3.454	667.3	1.3104
130	3.527	673.3	1.3206
140	3.600	679.2	1.3305
150	3.672	685.0	1.3401
160	3.743	690.8	1.3495
170	3.813	696.6	1.3588
180	3.883	702.3	1.3678
190	3.952	708.0	1.3767
200	4.021	713.7	1.3854
210	4.090	719.4	1.3940
220	4.158	725.1	1.4024
230	4.226	730.8	1.4108
240	4.294	736.5	1.4190
250	4.361	742.2	1.4271
260	4.428	747.9	1.4350
270	4.495	753.6	1.4429
280	4.562	759.4	1.4507
290	4.629	765.1	1.4584
300	4.695	770.8	1.4660
310	4.761	776.6	1.4736
320	4.827	782.4	1.4810
330	4.893	788.2	1.4884
340	4.959	794.0	1.4957
350	5.024	799.8	1.5029

Tem. °F. t	Abs. Pressure **110** lb./in.² Gage Press. **95.3** lb./in.² (Sat'n Temp. 61.21° F.) Volume ft.³/lb. V	Heat Content Btu./lb. H	Entropy Btu./lb. °F. S
(at sat'n)	*(2.693)*	*(627.5)*	*(1.2275)*
60	......	......	......
70	2.761	633.7	1.2392
80	2.837	640.5	1.2519
90	2.910	647.0	1.2640
100	2.981	653.4	1.2755
110	3.051	659.7	1.2866
120	3.120	665.8	1.2972
130	3.188	671.9	1.3076
140	3.255	677.8	1.3176
150	3.321	683.7	1.3274
160	3.386	689.6	1.3370
170	3.451	695.4	1.3463
180	3.515	701.2	1.3555
190	3.579	707.0	1.3644
200	3.642	712.8	1.3732
210	3.705	718.5	1.3819
220	3.768	724.3	1.3904
230	3.830	730.0	1.3988
240	3.892	735.7	1.4070
250	3.954	741.5	1.4151
260	4.015	747.2	1.4232
270	4.076	752.9	1.4311
280	4.137	758.7	1.4389
290	4.198	764.5	1.4466
300	4.259	770.2	1.4543
310	4.319	776.0	1.4619
320	4.379	781.8	1.4693
330	4.439	787.6	1.4767
340	4.500	793.4	1.4841
350	4.559	799.3	1.4859

Tem. °F.	Abs. Pressure **120** lb./in.² Gage Press. **105.3** lb./in.² (Sat'n Temp. 66.02° F.)		
(at sat'n)	*(2.476)*	*(628.4)*	*(1.2201)*
70	2.505	631.3	1.2255
80	2.576	638.3	1.2386
90	2.645	645.0	1.2510
100	2.712	651.6	1.2628
110	2.778	658.0	1.2741
120	2.842	664.2	1.2850
130	2.905	670.4	1.2956
140	2.967	676.5	1.3058
150	3.029	682.5	1.3157
160	3.089	688.4	1.3254
170	3.149	694.3	1.3348
180	3.209	700.2	1.3441
190	3.268	706.0	1.3531
200	3.326	711.8	1.3620
210	3.385	717.6	1.3707
220	3.442	723.4	1.3793
230	3.500	729.2	1.3877
240	3.557	734.9	1.3960
250	3.614	740.7	1.4042
260	3.671	746.5	1.4123
270	3.727	752.2	1.4202
280	3.783	758.0	1.4281
290	3.839	763.8	1.4359
300	3.895	769.6	1.4435
310	3.951	775.4	1.4511
320	4.006	781.2	1.4586
330	4.061	787.0	1.4660
340	4.117	792.9	1.4734
350	4.172	798.7	1.4807

Tem. °F.	Abs. Pressure **130** lb./in.² Gage Press. **115.3** lb./in.² (Sat'n Temp. 70.53° F.)		
(at sat'n)	*(2.291)*	*(629.2)*	*(1.2132)*
70	......	......	......
80	2.355	636.0	1.2260
90	2.421	643.0	1.2388
100	2.484	649.7	1.2509
110	2.546	656.3	1.2625
120	2.606	662.7	1.2736
130	2.665	668.9	1.2843
140	2.724	675.1	1.2947
150	2.781	681.2	1.3048
160	2.838	687.2	1.3146
170	2.894	693.2	1.3241
180	2.949	699.1	1.3335
190	3.004	705.0	1.3426
200	3.059	710.9	1.3516
210	3.113	716.7	1.3604
220	3.167	722.5	1.3690
230	3.220	728.3	1.3775
240	3.273	734.1	1.3858
250	3.326	739.9	1.3941
260	3.379	745.7	1.4022
270	3.431	751.5	1.4102
280	3.483	757.3	1.4181
290	3.535	763.1	1.4259
300	3.587	769.0	1.4336
310	3.639	774.8	1.4412
320	3.690	780.6	1.4487
330	3.742	786.5	1.4562
340	3.793	792.3	1.4636
350	3.844	798.2	1.4709

Tem. °F.	Abs. Pressure **140** lb./in.² Gage Press. **125.3** lb./in.² (Sat'n Temp. 74.79° F.)		
(at sat'n)	*(2.132)*	*(629.9)*	*(1.2068)*
80	2.166	633.8	1.2140
90	2.228	640.9	1.2272
100	2.288	647.8	1.2396
110	2.347	654.5	1.2515
120	2.404	661.1	1.2628
130	2.460	667.4	1.2738
140	2.515	673.7	1.2843
150	2.569	679.9	1.2945
160	2.622	686.0	1.3045
170	2.675	692.0	1.3141
180	2.727	698.0	1.3236
190	2.779	704.0	1.3328
200	2.830	709.9	1.3418
210	2.880	715.8	1.3507
220	2.931	721.6	1.3594
230	2.981	727.5	1.3679
240	3.030	733.3	1.3763
250	3.080	739.2	1.3846
260	3.129	745.0	1.3928
270	3.179	750.8	1.4008
280	3.227	756.7	1.4088
290	3.275	762.5	1.4166
300	3.323	768.3	1.4243
310	3.371	774.2	1.4320
320	3.420	780.0	1.4395
330	3.467	785.9	1.4470
340	3.515	791.8	1.4544
350	3.563	797.7	1.4617
360	3.610	803.6	1.4690

NOTE:—"V" is Volume of Superheated Vapor, ft.³/lb., "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

TABLE XX—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SUPERHEATED AMMONIA VAPORS—*Continued*

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

Tem. °F.	Abs. Pressure **150** lb./in.² Gage Pressure **135.3** lb./in.² (Sat'n Temp. 78.81° F.)			Tem. °F.	Abs. Pressure **160** lb./in.² Gage Pressure **154.3** lb./in.² (Sat'n Temp. 82.64° F.)			Abs. Pressure **170** lb./in.² Gage Pressure **155.3** lb./in.² (Sat'n Temp. 86.29° F.)			Abs. Pressure **180** lb./in.² Gage Pressure **165.3** lb./in.² (Sat'n Temp. 89.78° F.)		
t	*V*	*H*	*S*	*t*	*V*	*H*	*S*	*V*	*H*	*S*	*V*	*H*	*S*
(at sat'n)	(1.994)	(630.5)	(1.2009)	(at sat'n)	(1.872)	(631.1)	(1.1952)	(1.764)	(631.6)	(1.1900)	(1.667)	(632.0)	(1.1850)
80	2.001	631.4	1.2025	90	1.914	636.6	1.2055	1.784	634.4	1.1952	1.668	632.2	1.1853
90	2.061	638.8	1.2161	**100**	1.969	643.9	1.2186	1.837	641.9	1.2087	1.720	639.9	1.1992
100	2.118	645.9	1.2289	110	2.023	651.0	1.2311	1.889	649.1	1.2215	1.770	647.3	1.2123
110	2.174	652.8	1.2410	120	2.075	657.8	1.2429	1.939	656.1	1.2336	1.818	654.4	1.2247
120	2.228	659.4	1.2526	130	2.125	664.4	1.2542	1.988	662.8	1.2452	1.865	661.3	1.2364
130	2.281	665.9	1.2638	140	2.175	670.9	1.2652	2.035	669.4	1.2563	1.910	668.0	1.2477
140	2.334	672.3	1.2745	**150**	2.224	677.2	1.2757	2.081	675.9	1.2669	1.955	674.6	1.2586
150	2.385	678.6	1.2849	160	2.272	683.5	1.2859	2.127	682.3	1.2773	1.999	681.0	1.2691
160	2.435	684.8	1.2949	170	2.319	689.7	1.2958	2.172	688.5	1.2873	2.042	687.3	1.2792
170	2.485	690.9	1.3047	180	2.365	695.8	1.3054	2.216	694.7	1.2971	2.084	693.6	1,2891
180	2.534	696.9	1.3142	190	2.411	701.9	1.3148	2.260	700.8	1.3066	2.126	699.8	1.2987
190	2.583	702.9	1.3236	**200**	2.457	707.9	1.3240	2.303	706.9	1.3159	2.167	705.9	1.3081
200	2.631	708.9	1.3327	210	2.502	713.9	1.3331	2.346	713.0	1.3249	2.208	712.0	1.3172
210	2.679	714.8	1.3416	220	2.547	719.9	1.3419	2.389	719.0	1.3338	2.248	718.1	1.3262
220	2.726	720.7	1.3504	230	2.591	725.8	1.3506	2.431	724.9	1.3426	2.288	724.1	1.3350
230	2.773	726.6	1.3590	240	2.635	731.7	1.3591	2.473	730.9	1.3512	2.328	730.1	1.3436
240	2.820	732.5	1.3675	**250**	2.679	737.6	1.3675	2.514	736.8	1.3596	2.367	736.1	1.3521
250	2.866	738.4	1.3758	260	2.723	743.5	1.3757	2.555	742.8	1.3679	2.407	742.0	1.3605
260	2.912	744.3	1.3840	270	2.766	749.4	1.3838	2.596	748.7	1.3761	2.446	748.0	1.3687
270	2.958	750.1	1.3921	280	2.809	755.3	1.3919	2.637	754.6	1.3841	2.484	753.9	1.3768
280	3.004	756.0	1.4001	290	2.852	761.2	1.3998	2.678	760.5	1.3921	2.523	759.9	1.3847
290	3.049	761.8	1.4079	**300**	2.895	767.1	1.4076	2.718	766.4	1.3999	2.561	765.8	1.3926
300	3.095	767.7	1.4157	310	2.937	773.0	1.4153	2.758	772.3	1.4076	2.599	771.7	1.4004
310	3.140	773.6	1.4234	320	2.980	778.9	1.4229	2.798	778.3	1.4153	2.637	777.7	1.4081
320	3.185	779.4	1.4310	330	3.022	784.8	1.4304	2.838	784.2	1.4228	2.675	783.6	1.4156
330	3.230	785.3	1.4385	340	3.064	790.7	1.4379	2.878	790.1	1.4303	2.713	789.6	1.4231
340	3.274	791.2	1.4459	**350**	3.106	796.6	1.4452	2.918	796.2	1.4377	2.750	795.6	1.4305
350	3.319	797.1	1.4532	360	3.148	802.5	1.4525	2.957	802.0	1.4450	2.788	801.5	1.4379
360	3.364	803.0	1.4605	370	3.189	808.5	1.4597	2.997	808.0	1.4522	2.825	807.5	1.4451
				380	3.231	814.5	1.4669	3.036	814.0	1.4594	2.863	813.5	1.4523
				390	3.273	820.4	1.4740	3.075	820.0	1.4665	2.900	819.5	1.4594
				400	3.314	826.4	1.4810	3.114	826.0	1.4735	2.937	825.5	1.4665

Tem °F.	Abs. Pressure **190** lb./in.² Gage Pressure **175.3** lb./in.² (Sat'n Temp. 93.13° F.)			Tem °F.	Abs. Pressure **200** lb./in.² Gage Pressure **185.3** lb./in.² (Sat'n Temp. 96.34° F.)			Abs. Pressure **210** lb./in.² Gage Pressure **195.3** lb./in.² (Sat'n Temp. 99.43° F.)			Abs. Pressure **220** lb./in.² Gage Pressure **205.3** lb./in.² (Sat'n Temp. 102.42° F.)		
(at sat'n)	(1.581)	(632.4)	(1.1802)	(at sat'n)	(1.502)	(632.7)	(1.1756)	(1.431)	(633.0)	(1.1713)	(1.367)	(633.2)	(1.1671)
90	......	......	......	**100**	1.520	635.6	1.1809	......	......	......	......	......	......
100	1.615	637.8	1.1899	110	1.567	643.4	1.1947	1.480	641.5	1.1863	1.400	639.4	1.1781
110	1.663	645.4	1.2034	120	1.612	650.9	1.2077	1.524	649.1	1.1996	1.443	647.3	1.1917
120	1.710	652.6	1.2160	130	1.656	658.1	1.2200	1.566	656.4	1.2121	1.485	654.8	1.2045
130	1.755	659.7	1.2281	140	1.698	665.0	1.2317	1.608	663.5	1.2240	1.525	662.0	1.2167
140	1.799	666.5	1.2396	**150**	1.740	671.8	1.2429	1.648	670.4	1.2354	1.564	669.0	1.2281
150	1.842	673.2	1.2506	160	1.780	678.4	1.2537	1.687	677.1	1.2464	1.601	675.8	1.2394
160	1.884	679.7	1.2612	170	1.820	684.9	1.2641	1.725	683.7	1.2569	1.638	682.5	1.2501
170	1.925	686.1	1.2715	180	1.859	691.3	1.2742	1.762	690.2	1.2672	1.675	689.1	1.2604
180	1.966	692.5	1.2815	190	1.897	697.7	1.2840	1.799	696.6	1.2771	1.710	695.5	1.2704
190	2.005	698.7	1.2912	**200**	1.935	703.9	1.2935	1.836	702.9	1.2867	1.745	701.9	1.2801
200	2.045	704.9	1.3007	210	1.972	710.1	1.3029	1.872	709.2	1.2961	1.780	708.2	1.2896
210	2.084	711.1	1.3099	220	2.009	716.3	1.3120	1.907	715.3	1.3053	1.814	714.4	1.2989
220	2.123	717.2	1.3189	230	2.046	722.4	1.3209	1.942	721.5	1.3143	1.848	720.6	1.3079
230	2.161	723.2	1.3278	240	2.082	728.4	1.3296	1.977	727.6	1.3231	1.881	726.8	1.3168
240	2.199	729.3	1.3365	**250**	2.118	734.5	1.3382	2.011	733.7	1.3317	1.914	732.9	1.3255
250	2.236	735.3	1.3450	260	2.154	740.5	1.3467	2.046	739.8	1.3402	1.947	739.0	1.3340
260	2.274	741.3	1.3534	270	2.189	746.5	1.3550	2.080	745.8	1.3486	1.980	745.1	1.3424
270	2.311	747.3	1.3617	280	2.225	752.5	1.3631	2.113	751.8	1.3568	2.012	751.1	1.3507
280	2.348	753.2	1.3698	290	2.260	758.5	1.3712	2.147	757.9	1.3649	2.044	757.2	1.3588
290	2.384	759.2	1.3778	**300**	2.295	764.5	1.3791	2.180	763.9	1.3728	2.076	763.2	1.3668
300	2.421	765.2	1.3857	310	2.329	770.5	1.3869	2.213	769.9	1.3806	2.108	769.3	1.3747
310	2.457	771.1	1.3935	320	2.364	776.5	1.3947	2.246	775.9	1.3884	2.140	775.3	1.3825
320	2.493	777.1	1.4012	330	2.398	782.5	1.4023	2.279	781.9	1.3961	2.171	781.3	1.3902
330	2.529	783.1	1.4088	340	2.432	788.5	1.4099	2.312	787.9	1.4037	2.203	787.4	1.3978
340	2.565	789.0	1.4168	**350**	2.466	794.5	1.4173	2.345	794.0	1.4112	2.234	793.5	1.4053
350	2.601	795.1	1.4238	360	2.500	800.5	1.4241	2.377	800.0	1.4186	2.265	799.5	1.4127
360	2.637	801.0	1.4311	370	2.534	806.5	1.4320	2.409	806.0	1.4259	2.296	805.5	1.4200
370	2.672	807.0	1.4384	380	2.568	812.5	1.4392	2.442	812.0	1.4331	2.327	811.6	1.4273
380	2.707	813.0	1.4456	390	2.601	818.6	1.4464	2.474	818.1	1.4403	2.358	817.6	1.4345
390	2.743	819.0	1.4527	**400**	2.635	824.6	1.4534	2.506	824.2	1.4474	2.388	823.7	1.4416
400	2.778	825.1	1.4598										

NOTE:—"V" is Volume of Superheated Vapor, ft.³/lb.; "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

TABLE XX.—BUREAU OF STANDARDS TABLES OF PROPERTIES OF SUPERHEATED AMMONIA VAPORS.—(*Continued.*)

Bureau of Standards Circular No. 142, April 16, 1923. Rearranged and Extended for The American Society of Refrigerating Engineers, July, 1925.

Temp °F	Abs Pressure 230 lb./in.² Gage Pressure **215.3** lb./in.² (Sat'n Temp. 105.30° F.)			Abs. Pressure 240 lb./in.² Gage Pressure **225.3** lb./in.² (Sat'n. Temp. 108.09° F.)			Abs. Pressure 250 lb./in.² Gage Pressure **235.3** lb./in.² (Sat'n. Temp. 110.80° F.)			Abs. Pressure 260 lb./in.² Gage Pressure **245.3** lb./in.² (Sat'n. Temp. 113.12° F.)		
°F	**V**	**H**	**S**	**V**	**H**	**S**	**V**	**H**	**S**	**V**	**H**	**S**
(at sat'n)	*(1.307)*	*(633.4)*	*(1.1631)*	*(1.253)*	*(633.6)*	*(1.1592)*	*([illegible])*	*([illegible])*	*([illegible])*	*(1.155)*	*([illegible])*	*([illegible])*
110	1.328	637.4	1.1700	1.261	635.3	1.1621						
120	1.370	645.4	1.1840	1.302	643.5	1.1764	1.240	641.5	1.1690	1.182	639.5	1.1617
130	1.410	653.1	1.1971	1.342	651.3	1.1898	1.278	649.6	1.1827	1.220	647.8	1.1757
140	1.449	660.4	1.2095	1.380	658.8	1.2025	1.316	657.2	1.1956	1.257	655.6	1.1889
150	1.487	667.6	1.2213	1.416	666.1	1.2145	1.352	664.6	1.2078	1.292	663.1	1.2014
160	1.524	674.5	1.2325	1.452	673.1	1.2259	1.386	671.8	1.2195	1.326	670.4	1.2132
170	1.559	681.3	1.2434	1.487	680.0	1.2369	1.420	678.7	1.2306	1.359	677.5	1.2245
180	1.594	687.9	1.2538	1.521	686.7	1.2475	1.453	685.5	1.2414	1.391	684.4	1.2354
190	1.629	694.4	1.2640	1.554	693.3	1.2577	1.486	692.2	1.2517	1.422	691.1	1.2458
200	1.663	700.9	1.2738	1.587	699.8	1.2677	1.518	698.8	1.2617	1.453	697.7	1.2560
210	1.696	707.2	1.2834	1.619	706.2	1.2773	1.549	705.3	1.2715	1.484	704.3	1.2658
220	1.729	713.5	1.2927	1.651	712.6	1.2867	1.580	711.7	1.2810	1.514	710.7	1.2754
230	1.762	719.8	1.3018	1.683	718.9	1.2959	1.610	718.0	1.2902	1.543	717.1	1.2847
240	1.794	726.0	1.3107	1.714	725.1	1.3049	1.640	724.3	1.2993	1.572	723.4	1.2938
250	1.826	732.1	1.3195	1.745	731.3	1.3137	1.670	730.5	1.3081	1.601	729.7	1.3027
260	1.857	738.3	1.3281	1.775	737.5	1.3224	1.699	736.7	1.3168	1.630	736.0	1.3115
270	1.889	744.4	1.3365	1.805	743.6	1.3308	1.729	742.9	1.3253	1.658	742.2	1.3200
280	1.920	750.5	1.3448	1.835	749.8	1.3392	1.758	749.1	1.3337	1.686	748.4	1.3285
290	1.951	756.5	1.3530	1.865	755.9	1.3474	1.786	755.2	1.3420	1.714	754.5	1.3367
300	1.982	762.6	1.3610	1.895	762.0	1.3554	1.815	761.3	1.3501	1.741	760.7	1.3449
310	2.012	768.7	1.3689	1.924	768.0	1.3633	1.843	767.4	1.3581	1.769	766.8	1.3529
320	2.043	774.7	1.3767	1.954	774.1	1.3712	1.872	773.5	1.3659	1.796	772.9	1.3608
330	2.073	780.8	1.3844	1.983	780.2	1.3790	1.900	779.6	1.3737	1.823	779.0	1.3686
340	2.103	786.8	1.3921	2.012	786.3	1.3866	1.928	785.7	1.3814	1.850	785.2	1.3763
350	2.133	793.0	1.3996	2.040	792.4	1.3942	1.955	791.9	1.3889	1.877	791.4	1.3839
360	2.163	798.9	1.4070	2.069	798.4	1.4016	1.983	797.9	1.3964	1.904	797.4	1.3914
370	2.193	805.0	1.4144	2.098	804.5	1.4090	2.011	804.0	1.4038	1.930	803.5	1.3988
380	2.222	811.1	1.4217	2.126	810.6	1.4163	2.038	810.1	1.4111	1.957	809.6	1.4062
390	2.252	817.2	1.4289	2.155	816.7	1.4235	2.065	816.2	1.4183	1.983	815.8	1.4134
400	2.281	823.3	1.4360	2.183	822.8	1.4307	2.093	822.3	1.4255	2.009	821.9	1.4206

Temp °F	Abs Pressure 270 lb./in.² Gage Pressure **255.3** lb./in.² (Sat'n. Temp. 115.97° F.)			Abs. Pressure 280 lb./in.² Gage Pressure **265.3** lb./in.² (Sat'n. Temp. 118.45° F.)			Abs. Pressure 290 lb./in.² Gage Pressure **275.3** lb./in.² (Sat'n. Temp. 120.86° F.)			Abs. Pressure 300 lb./in.² Gage Pressure **285.3** lb./in.² (Sat'n. Temp. 123.21° F.)		
(at sat'n)	*(1.112)*	*(633.9)*	*(1.1483)*	*(1.07[illegible])*	*(634.0)*	*(1.1449)*	*(1.034)*	*(634.0)*	*(1.1415)*	*(0.999)*	*(634.0)*	*(1.1383)*
120	1.128	637.5	1.1544	1.078	635.4	1.1473						
130	1.166	645.9	1.1689	1.115	644.0	1.1621	1.068	642.1	1.1554	1.023	640.1	1.1487
140	1.202	653.9	1.1823	1.151	652.2	1.1759	1.103	650.5	1.1695	1.058	648.7	1.1632
150	1.236	661.6	1.1950	1.184	660.1	1.1888	1.136	658.5	1.1827	1.091	656.9	1.1767
160	1.26[illegible]	669.0	1.2071	1.217	667.6	1.2011	1.168	666.1	1.1952	1.123	664.7	1.1894
170	1.302	676.2	1.2185	1.249	674.9	1.2127	1.199	673.5	1.2070	1.153	672.2	1.2014
180	1.333	683.2	1.2296	1.279	681.9	1.2239	1.229	680.7	1.2183	1.183	679.5	1.2129
190	1.364	690.0	1.2401	1.309	688.9	1.2346	1.259	687.7	1.2292	1.211	686.5	1.2239
200	1.394	696.7	1.2504	1.339	695.6	1.2449	1.287	694.6	1.2396	1.239	693.5	1.2344
210	1.423	703.3	1.2603	1.367	702.3	1.2550	1.315	701.3	1.2497	1.267	700.3	1.2447
220	1.452	709.8	1.2700	1.396	708.8	1.2647	1.343	707.9	1.2596	1.294	706.9	1.2546
230	1.481	716.2	1.2794	1.424	715.3	1.2742	1.370	714.4	1.2691	1.320	713.5	1.2642
250	1.509	772.6	1.2885	1.451	721.8	1.2834	1.397	720.9	1.2784	1.346	720.0	1.2736
250	1.537	728.9	1.2975	1.478	728.1	1.2924	1.423	727.3	1.2875	1.372	726.5	1.2827
260	1.565	735.2	1.3063	1.505	734.4	1.3013	1.449	733.7	1.2964	1.397	732.9	1.2917
270	1.592	741.4	1.3149	1.532	740.7	1.3099	1.475	740.0	1.3051	1.422	739.2	1.3004
280	1.620	747.7	1.3234	1.558	747.0	1.3184	1.501	746.3	1.3137	1.447	745.5	1.3090
290	1.646	753.9	1.3317	1.584	753.2	1.3268	1.526	752.5	1.3221	1.472	751.8	1.3175
300	1.673	760.0	1.3399	1.610	759.4	1.3350	1.551	758.7	1.3303	1.496	758.1	1.3257
310	1.700	766.2	1.3480	1.635	765.6	1.3431	1.576	764.9	1.3384	1.520	764.3	1.3338
320	1.726	772.3	1.3559	1.661	771.7	1.3511	1.601	771.1	1.3464	1.544	770.5	1.3419
330	1.752	778.5	1.3647	1.686	777.9	1.3590	1.625	777.3	1.3543	1.568	776.7	1.3498
340	1.778	784.6	1.3714	1.712	784.0	1.3667	1.650	783.5	1.3621	1.592	782.9	1.3576
350	1.804	790.8	1.3790	1.737	790.3	1.3743	1.674	789.7	1.3697	1.616	789.1	1.3653
360	1.830	796.9	1.3866	1.762	796.3	1.3819	1.698	795.8	1.3773	1.639	795.3	1.3729
370	1.856	803.0	1.3940	1.787	802.5	1.3893	1.722	802.0	1.3848	1.662	801.5	1.3804
380	1.881	809.1	1.4014	1.811	808.7	1.3967	1.747	808.2	1.3922	1.686	807.7	1.3878
390	1.907	815.3	1.4086	1.836	814.8	1.4040	1.770	814.3	1.3995	1.709	813.9	1.3951
400	1.932	821.4	1.4158	1.861	821.0	1.4112	1.794	820.5	1.4067	1.732	820.1	1.4024

NOTE.—"V" is Volume of Superheated Vapor, ft.³/lb., "H" is Heat Content, Btu./lb., and "S" is Entropy, Btu./lb. °F.

TABLE XXI.—PROPERTIES OF SATURATED CARBON DIOXIDE VAPOR—CO_2 (Temperature Table)

Mollier (Amagat), Hodsdon, Ice and Cold Storage, London (1914).

Temp.	Pressure			Volume		Density		Heat Content Above 32° F.			Entropy From 32° F.			
°F.	Abs. lb./in.²	Gage† Atmos at /in.²	Gage† lb./in.²	Liquid ft.³/lb.	Vapor ft.³/lb.	Liquid lb./ft.³	Vapor lb./ft.³	Liquid Btu./lb.	Latent Btu./lb	Vapor Btu./lb.	Liquid Btu./lb.	Evap. Btu./lb.	Vapor Btu./lb.	Temp. °F.
t	p	$a-gp$	gp	v	V	$1/v$	$1/V$	$h+$	$L=$	H	s	L/T	S	t
−22	212.9	13.48	198.2	0.0155	0.4319	64.52	2.315	−24.78	126.7	102.0	−0.0533	0.2898	0.2365	−22
−21	216.7	13.74	202.0	.0155	.4242	64.43	2.358	−24.37	126.4	102.0	− .0524	.2883	.2359	−21
−20	220.6	14.00	205.9	0.0155	0.4166	64.34	2.401	−23.96	126.0	102.0	−0.0514	0.2867	0.2353	−20
−19	224.4	14.27	209.7	.0156	.4091	64.25	2.444	−23.54	125.6	102.1	− .0505	.2852	.2348	−19
−18	228.4	14.53	213.7	.0156	.4018	64.15	2.489	−23.13	125.2	102.1	− .0495	.2837	.2342	−18
−17	232.3	14.80	217.6	.0156	.3946	64.05	2.534	−22.71	124.9	102.1	− .0486	.2822	.2336	−17
−16	236.4	15.08	221.7	.0156	.3876	63.94	2.580	−22.30	124.5	102.2	− .0476	.2807	.2331	−16
−15	240.5	15.36	225.8	0.0157	0.3807	63.84	2.627	−21.88	124.1	102.2	−0.0467	0.2792	0.2325	−15
−14	244.6	15.64	229.9	.0157	.3739	63.73	2.674	−21.46	123.7	102.2	− .0458	.2777	.2319	−14
−13	248.8	15.92	234.1	.0157	.3673	63.61	2.723	−21.03	123.3	102.2	− .0448	.2761	.2313	−13
−12	253.0	16.21	238.3	.0157	.3608	63.49	2.772	−20.61	122.9	102.3	− .0439	.2746	.2307	−12
−11	258.3	16.50	242.6	.0158	.3544	63.37	2.822	−20.18	122.5	102.3	− .0429	.2731	.2302	−11
−10	261.7	16.80	247.0	0.0158	0.3482	63.25	2.872	−19.76	122.0	102.3	−0.0420	0.2716	0.2296	−10
− 9	266.1	17.10	251.4	.0158	.3420	63.13	2.924	−19.33	121.6	102.3	− .0410	.2700	.2290	− 9
− 8	270.6	17.41	255.9	.0159	.3360	63.01	2.976	−18.90	121.2	102.3	− .0401	.2685	.2284	− 8
− 7	275.1	17.72	260.4	.0159	.3301	62.88	3.029	−18.47	120.8	102.3	− .0391	.2669	.2278	− 7
− 6	279.7	18.03	265.0	.0159	.3243	62.76	3.083	−18.04	120.3	102.3	− .0382	.2654	.2273	− 6
− 5	284.4	18.35	269.7	0.0160	0.3186	62.63	3.138	−17.61	119.9	102.3	−0.0372	0.2639	0.2267	− 5
− 4	289.1	18.67	274.4	.0160	.3131	62.50	3.194	−17.17	119.5	102.3	− .0362	.2623	2261	− 4
− 3	293.9	18.99	279.2	.0160	.3076	62.37	3.251	−16.73	119.0	102.3	− .0353	.2608	.2255	− 3
− 2	298.7	19.32	284.0	.0161	.3022	62.23	3.309	−16.29	118.6	102.3	− .0343	.2592	.2249	− 2
− 1	303.6	19.66	288.9	.0161	.2969	62.09	3.368	−15.85	118.1	102.3	− .0334	.2577	.2243	− 1
0	308.6	20.00	293.9	0.0161	0.2918	61.95	3.427	−15.41	117.7	102.2	−0.0324	0.2561	0.2237	0
1	313.7	20.34	299.0	.0162	.2867	61.80	3.488	−14.96	117.2	102.2	− .0314	.2545	.2231	1
2	318.7	20.68	304.0	.0162	.2817	61.65	3.550	−14.51	116.7	102.2	− .0304	.2530	.2225	2
3	323.9	21.03	309.2	.0163	.2768	61.51	3.612	−14.07	116.2	102.2	− .0295	.2514	.2219	3
4	329.1	21.39	314.4	.0163	.2720	61.36	3.676	−13.61	115.8	102.1	− .0285	.2498	.2213	4
‡5	**334.4**	**21.75**	**319.7**	**0.0163**	**0.2673**	**61.22**	**3.741**	**−13.16**	**115.3**	**102.1**	**−0.0275**	**0.2482**	**0.2207**	**5‡**
6	339.8	22.11	325.1	.0164	.2627	61.07	3.807	−12.71	114.8	102.1	− .0266	.2466	.2201	6
7	345.2	22.48	330.5	.0164	.2581	60.92	3.874	−12.25	114.3	102.0	− .0256	.2451	.2195	7
8	350.7	22.85	336.0	.0165	.2537	60.77	3.942	−11.79	113.8	102.0	− .0246	.2435	.2189	8
9	356.2	23.23	341.5	.0165	.2493	60.63	4.011	−11.33	113.3	102.0	− .0236	.2419	.2183	9
10	361.8	23.61	347.1	0.0165	0.2450	60.48	4.082	−10.87	112.8	101.9	−0.0226	0.2402	0.2176	10
11	367.5	24.00	352.8	.0166	.2408	60.33	4.154	−10.40	112.3	101.9	− .0216	.2386	.2170	11
12	373.3	24.39	358.6	.0166	.2366	60.18	4.227	− 9.934	111.7	101.8	− .0206	.2370	.2164	12
13	379.1	24.79	364.4	.0167	.2325	60.03	4.301	− 9.464	111.2	101.7	− .0196	.2354	.2158	13
14	385.0	25.19	370.3	.0167	.2285	59.88	4.377	− 8.992	110.7	101.7	− .0186	.2338	.2151	14
15	391.0	25.60	376.3	0.0167	0.2245	59.73	4.454	− 8.515	110.1	101.6	−0.0176	0.2321	0.2145	15
16	397.1	26.01	382.4	.0168	.2207	59.58	4.532	− 8.038	109.6	101.5	− .0166	.2305	.2139	16
17	403.2	26.43	388.5	.0168	.2168	59.42	4.611	− 7.557	109.0	101.5	− .0156	.2288	.2132	17
18	409.4	26.85	394.7	.0169	.2131	59.27	4.692	− 7.076	108.5	101.4	− .0146	.2272	.2126	18
19	415.7	27.28	401.0	.0169	.2094	59.11	4.775	− 6.591	107.9	101.3	− .0136	.2255	.2119	19
20	422.0	27.71	407.3	0.0170	0.2058	58.95	4.859	− 6.102	107.3	101.2	−0.0126	0.2239	0.2113	20
21	428.4	28.14	413.7	.0170	.2023	58.79	4.944	− 5.610	106.7	101.1	− .0115	.2222	.2106	21
22	434.9	28.58	420.2	.0171	.1987	58.64	5.031	− 5.117	106.1	101.0	− .0105	.2205	.2100	22
23	441.4	29.03	426.7	.0171	.1953	58.47	5.120	− 4.621	105.6	100.9	− .0095	.2188	.2093	23
24	448.1	29.48	433.4	.0172	.1919	58.31	5.211	− 4.121	104.9	100.8	− .0085	.2171	.2087	24
25	454.8	29.94	440.1	0.0172	0.1886	58.14	5.303	− 3.618	104.3	100.7	−0.0074	0.2154	0.2080	25
26	461.6	30.40	446.9	.0172	.1853	57.98	5.396	− 3.111	103.7	100.6	− .0064	.2137	.2073	26
27	468.5	30.87	453.8	.0173	.1821	57.81	5.492	− 2.601	103.1	100.5	− .0053	.2120	.2066	27
28	475.4	31.34	460.7	0174	.1789	57.64	5.589	− 2.087	102.5	100.4	− .0043	.2102	.2059	28
29	482.5	31.82	467.8	.0174	.1758	57.47	5.688	− 1.570	101.8	100.2	− .0032	.2085	.2053	29

*Rearranged and symbols changed, to conform to A. S. R. E. Standard, by Editor A. S. R. E. Data.

†Gage pressure supplied by Editor A. S. R. E. Data.

‡Standard ton temperatures.

TABLE XXI.—PROPERTIES OF SATURATED CARBON DIOXIDE VAPOR—CO_2 (Temperature Table)—(*Continued*)

Temp.	Pressure			Volume		Density		Heat Content Above 32° F.			Entropy From 32° F.			Temp
°F.	Abs. lb./in.²	Gage† Atmos at./in.²	Gage† lb./in.²	Liquid ft.³/lb	Vapor ft.³/lb	Liquid lb./ft.³	Vapor lb./ft.³	Liquid Btu./lb.	Latent Btu./lb	Vapor Btu./lb.	Liquid Btu./lb.	Evap. Btu./lb.	Vapor Btu./lb.	°F
t	*p*	*a-g p*	*g p*	*v*	*V*	*1/v*	*1/V*	*h+*	*L=*	*H*	*s*	*L/T*	*S*	*t*
30	489.6	32.31	474.9	0.0175	0.1728	57.30	5.789	− 1.049	101.2	100.1	−0.0021	0.2067	0.2046	**30**
31	496.8	32.79	482.1	.0175	.1697	57.12	5.892	− 0.525	100.5	99.98	− .0011	.2049	.2039	31
32	504.1	33.29	489.4	.0176	.1668	56.95	5.996	0.000	99.83	99.83	− .0000	.2032	.2032	32
33	511.4	33.79	496.7	.0176	.1639	56.77	6.103	+ 0.531	99.16	99.69	+ .0011	.2014	.2025	33
34	518.9	34.30	504.2	.0177	.1610	56.59	6.212	+ 1.066	98.47	99.54	+ .0022	.1996	.2017	34
35	526.4	34.81	511.7	0.0177	0.1581	56.41	6.323	1.604	97.77	99.38	0.0033	0.1978	0.2010	**35**
36	534.0	35.33	519.3	.0178	.1554	56.22	6.437	2.149	97.07	99.22	.0044	.1959	.2003	36
37	541.7	35.85	527.0	.0178	.1526	56.03	6.553	2.697	96.35	99.05	.0055	.1941	.1996	37
38	549.5	36.38	534.8	.0179	.1499	55.84	6.671	3.248	95.62	98.87	.0066	.1922	1988	38
39	557.4	36.92	542.7	.0180	.1472	55.65	6.792	3.806	94.88	98.69	.0077	1904	.1981	39
40	565.4	37.46	550.7	0.0180	0.1446	55.45	6.915	4.367	94.13	98.50	0.0088	0.1885	0 1973	**40**
41	573.4	38.01	558.7	.0181	.1420	55.25	7.040	4.932	93.37	98.31	.0099	.1866	.1965	41
42	581.6	38.56	566.9	.0182	.1395	55.04	7.169	5.503	92.60	98.10	0111	.1847	.1958	42
43	589.8	39.12	575.1	.0182	.1370	54.84	7.300	6.080	91.82	97.90	.0122	.1828	.1950	43
44	598.1	39.69	583.4	.0183	.1345	54.62	7.434	6.664	91.02	97.68	0134	.1808	.1942	44
45	606.5	40.26	591.8	0.0184	0.1321	54.41	7.571	7.251	90.21	97.46	0.0146	0.1788	0.1934	**45**
46	615.0	40.84	600.3	.0185	.1297	54.19	7.711	7.844	89.39	97.23	.0157	.1769	.1926	46
47	623.6	41.43	608.9	.0185	.1273	53.97	7.854	8.443	88.55	96.99	.0169	.1749	.1918	47
48	632.3	42.02	617.6	.0186	.1250	53.74	8.000	9.049	87.70	96.75	.0181	.1729	.1910	48
49	641.1	42.63	626.4	.0187	.1227	53.51	8.151	9.664	86.83	96.50	.0193	.1708	.1901	49
50	650.0	43.22	635.3	0.0188	0.1204	53.28	8.304	10.28	85.95	96.24	0.0205	0.1687	0.1893	**50**
51	659.0	43.83	644.3	.0189	.1182	53.04	8.461	10.91	85.06	95.97	.0218	.1666	.1884	51
52	668.1	44.45	653.4	.0189	.1160	52.80	8.622	11.55	84.14	95.69	.0230	.1645	.1875	52
53	677.3	45.07	662.6	.0190	.1138	52.55	8.787	12.19	83.21	95.40	.0243	.1624	.1867	53
54	686.5	45.70	671.8	.0191	.1116	52.30	8.957	12.84	82.26	95.10	.0255	.1602	.1858	54
55	695.9	46.34	681.2	0.0192	0.1095	52.05	9.132	13.49	81.29	94.78	0.0268	0.1580	0.1849	**55**
56	705.4	46.98	690.7	.0193	.1074	51.79	9.313	14.16	80.30	94.46	.0281	.1558	.1839	56
57	714.9	47.63	700.2	.0194	.1053	51.53	9.497	14.84	79.30	94.13	.0294	.1536	.1830	57
58	724.6	48.29	709.9	.0195	.1032	51.26	9.686	15.53	78.27	93.79	.0307	.1513	.1820	58
59	734.3	48.96	719.6	.0196	.1012	50.99	9.880	16.22	77.22	93.44	.0321	.1490	.1811	59
60	744.2	49.63	729.5	0.0197	0.0992	50.71	10.08	16.93	76.14	93.07	0.0335	0.1466	0.1801	**60**
61	754.2	50.30	739.5	.0198	.0972	50.42	10.29	17.65	75.04	92.69	.0348	.1442	.1790	61
62	764.3	50.99	749.6	.0200	.0953	50.11	10.50	18.38	73.91	92.29	.0363	.1417	.1780	62
63	774.5	51.68	759.8	.0201	.0933	49.80	10.72	19.13	72.75	91.88	.0377	.1393	.1770	63
64	784.7	52.38	770.0	.0202	.0914	49.47	10.95	19.88	71.57	91.45	.0391	1367	.1759	64
65	795.1	53.09	780.4	0.0203	0.0894	49.14	11.18	20.66	70.35	91.01	0.0406	0.1342	0.1748	**65**
66	805.6	53.80	790.9	.0205	.0875	48.80	11.42	21.45	69.10	90.55	.0421	.1315	.1736	66
67	816.2	54.53	801.5	.0206	.0856	48.44	11.67	22.25	67.81	90.07	.0436	.1288	.1725	67
68	827.0	55.26	812.3	.0208	.0838	48.08	11.94	23.08	66.49	89.56	.0452	.1261	.1713	68
69	837.8	55.99	823.1	.0210	.0819	47.69	12.21	23.92	65.12	89.04	.0468	.1233	.1701	69
70	848.7	56.74	834.0	0.0211	0.0800	47.29	12.49	24.78	63.71	88.49	0.0484	0.1204	0.1688	**70**
71	859.8	57.49	845.1	.0213	.0782	46.87	12.82	25.67	62.25	87.92	.0501	.1174	.1675	71
72	870.9	58.25	856.2	.0215	.0763	46.44	13.10	26.58	60.74	87.32	.0518	.1143	1661	72
73	882.2	59.01	867.5	.0217	.0745	45.99	13.43	27.52	59.17	86.69	.0536	.1111	.1647	73
74	893.6	59.79	878.9	.0220	.0726	45.53	13.77	28.49	57.54	86.03	.0554	.1079	.1633	74
75	905.1	60.57	890.4	0.0222	0.0708	45.05	14.13	29.50	55.83	85.33	0.0573	0.1045	0.1618	**75**
76	916.7	61.36	902.0	.0224	.0689	44.56	14.51	30.54	54.05	84.59	.0592	.1010	.1602	76
77	928.4	62.16	913.7	.0227	.0671	44.06	14.90	31.62	52.17	83.80	.0613	.0973	.1585	77
78	940.3	62.96	925.6	.0230	.0652	43.55	15.34	32.76	50.20	82.96	.0634	.0934	.1568	78
79	952.2	63.78	937.5	.0232	.0633	43.04	15.81	33.95	48.11	82.06	.0656	.0894	.1550	79
80	964.3	64.60	949.6	0.0235	0 0613	42.50	16.32	35.21	45.88	81.09	0.0679	0.0851	0.1530	**80**
81	976.5	65.43	961.8	.0238	.0592	41.95	16.90	36.54	43.49	80.03	.0704	.0805	.1509	81
82	988.8	66.27	974.1	.0242	.0570	41.30	17.53	37.98	40.90	78.88	.0731	.0755	.1486	82
83	1001.0	67.11	986.3	.0246	.0548	40.62	18.25	39.53	38.07	77.60	.0759	.0702	.1461	83
84	1014.0	67.97	999.3	.0251	.0524	39.81	19.07	41.25	34.90	76.15	.0791	.0642	.1433	84
85	1027.0	68.83	1012.3	0.0258	0.0500	38.76	20.00	43.18	31.29	74.47	0.0826	0.0575	0.1401	**85**
86‡	**1039.0**	**69.70**	**1024.3**	**.0267**	**.0474**	**37.41**	**21.09**	**45.45**	**27.00**	**72.46**	**.0868**	**.0495**	**.1363**	**86‡**
87	1052.0	70.58	1037.3	.0283	.0446	35.34	22.42	48.32	21.52	69.84	.0921	.0394	.1314	87
88	1065.0	71.47	1050.3	.0305	.0401	32.79	24.95	52.78	12.84	65.62	1002	.0235	.1237	88
88.43	1071.0	71.86	1056.3	.0346	.0346	28.90	28.90	59.23	0.00	59.23	.1120	.0000	.1120	88.43

†Gage pressures supplied by Editor A. S. R. E. Data.
‡Standard ton temperatures.

TABLE XXII.—PROPERTIES OF SATURATED VAPOR OF BUTANE:—C_4H_{10}

Linde Air Products Company Laboratory. Refrigerating Engineering, June, 1926. A. S. R. E. Data Book.

Temp.	Pressure		Volume		Density		Heat Content Above 0° F.			Entropy From 0° F.		Temp.
° F.	Abs. lb./in.²	Gage lb./in.²	Liquid ft.³/lb.	Vapor ft.³/lb.	Liquid lb./ft.³	Vapor lb./ft.³	Liquid Btu./lb.	Latent Btu./lb.	Vapor Btu./lb.	Liquid Btu./lb.°F	Vapor Btu./lb.°F.	° F.
t	p	gp	v	V	$1/v$	$1/V$	h +	L =	H	s	S	t
0	7.3	15.0*	0 02591	11.1	38.59	0 0901	0.0	170.5	170.5	0 000	0.370	**0**
1	7 5	14.7	02593	10.9	38.56	0917	0.5	170.5	171.0	001	370	1
2	7.7	14 3	.02596	10.7	38.52	.0935	1.0	170.0	171 0	.002	370	2
3	7.8	13 9	.02598	10.4	38.49	.0962	1.5	170.0	171.5	.003	370	3
4	8 0	13.6	.02601	10 2	38.45	.0980	2.0	170.0	172.0	005	370	4
5‡	**8.2**	**13.2***	**0.02603**	**9.98**	**38.41**	**0.100**	**2.5**	**169.5**	**172.0**	**0.006**	**0.370**	**5‡**
6	8.4	12.8	02606	9.78	38.38	.102	3.0	169.5	172.5	007	370	6
7	8.6	12.4	02608	9.57	38.35	.104	3.5	169.5	173.0	008	370	7
8	8.8	12.0	.02610	9.37	38.31	.107	4.0	169.5	173.5	.009	370	8
9	9 0	11.6	.02612	9.16	38.28	.109	4.5	169 0	173.5	.010	.370	9
10	9.2	11.1*	0.02615	8.95	38.24	0.112	5.5	168.5	174.0	0.011	0.370	**10**
11	9.4	10.7	.02617	8.78	38.21	.114	6.0	168.5	174.5	.012	.370	11
12	9.7	10.3	.02619	8.59	38.18	.116	6.5	168.5	175.0	.013	.370	12
13	9.9	9.9	.02622	8.41	38.14	.119	7.0	168.0	175.0	.015	.370	13
14	10.1	9.5	.02624	8.22	38.11	.122	7.5	168.0	175.5	.016	.370	14
15	10.4	8.8*	0.02627	8.05	38.07	0.124	8.0	168.0	176.0	0.017	0.370	**15**
16	10 6	8.5	.02629	7.88	38.04	.127	8.5	167.5	176.0	.018	.371	16
17	10.8	8.0	.02632	7.72	38 00	.130	9.0	167.5	176.5	.019	.371	17
18	11.1	7.5	.02634	7.56	37.97	.132	9.5	167.5	177.0	.020	.371	18
19	11.3	7.0	.02636	7.40	37.93	.135	10.0	167.5	177.5	.021	.371	19
20	11.6	6.3*	0.02639	7.23	37.89	0.138	10.5	167.0	177.5	0.022	0.371	**20**
21	11.8	6.0	.02641	7.10	37.86	.141	11.0	167.0	178.0	.023	.371	21
22	12.1	5.5	.02643	6.97	37.83	.143	11.5	167.0	178.5	.025	.371	22
23	12.4	4.9	.02646	6.82	37.79	.147	12.0	166.5	178.5	.026	.371	23
24	12 7	4.3	.02648	6.68	37.76	.150	12.5	166.5	179.0	.027	.371	24
25	13.0	3.6*	0.02651	6.55	37.72	0.153	13.0	166.0	179.0	0.028	0.371	**25**
30	14.4	0.6*	.02664	5.90	37.54	.169	16.0	165.5	181.5	.033	.371	30
35	16.0	1.3	.02676	5.37	37.37	.186	19.0	164.5	183.5	.039	.371	35
40	17.7	3.0	.02689	4.88	37.19	.205	21.5	163.5	185.0	.044	.371	40
45	19.6	4.9	.02703	4.47	37.00	.224	24.5	162.5	187.0	.050	.372	45
50	21.6	6.9	0.02716	4.07	36.82	0.246	27.0	161.5	188.5	0.056	0.373	**50**
55	23.8	9.1	.02730	3.73	36.63	.268	30 0	160.5	190.5	.061	.373	55
60	26.3	11.6	.02743	3.40	36.45	.294	33.0	159.5	192.5	.067	.374	60
65	28.9	14.2	.02759	3.12	36.24	.321	36.0	158.5	194.5	.072	374	65
70	31.6	16.9	.02773	2.88	36.06	.347	38.5	157.5	196.0	.078	.375	70
75	34.5	19.8	0.02789	2.65	35.86	0.377	41.5	156.5	198.0	0.083	0.375	**75**
80	37.6	22.9	.02805	2.46	35.65	.407	44.5	155.0	199.5	.089	.376	80
85	40.9	26.2	.02821	2.28	35.45	.439	47.5	154.0	201.5	.094	.376	85
86‡	**41.6**	**26.9**	**.02825**	**2.24**	**35.40**	**.446**	**48.5**	**153.5**	**202.0**	**.095**	**.376**	**86‡**
90	44.5	29.8	.02838	2.10	35.24	.476	51.0	152.0	203.0	.100	.377	90
95	48.2	33.5	0.02854	1.96	35.04	0.510	54.0	151.0	205.0	0.105	0.377	**95**
100	52.2	37.5	.02870	1.81	34.84	.552	57.0	149.5	206.5	.111	.378	100
105	56.4	41.7	.02889	1.70	34.62	.588	60.5	148.0	208 5	117	.380	105
110	60.8	46.1	.02906	1.58	34.41	.633	63.5	147.0	210.5	122	.380	110
115	65 6	50.9	.02925	1.48	34.19	.676	66.5	145.5	212.0	.128	.381	115
120	70.8	56.1	0.02945	1.38	33.96	0.725	70.0	143.5	213.5	0.134	0.382	**120**
125	76.0	61.3	.02966	1.30	33.72	.769	73.5	142.0	215.5	.139	.382	125
130	81.4	66.7	.02986	1.21	33.49	.826	76.5	140.5	217.0	145	.384	130
135	87.0	72.3	.03009	1.14	33.23	.877	80.0	139.0	219.0	.151	385	135
140	92 6	77.9	.03032	1.07	32.98	.934	83.5	137.5	221.0	157	.386	140

* Inches of Mercury below one standard atmosphere (29.82 in = 14.696 lbs./sq. in. abs.)
‡Standard Ton Temperatures.

PROPERTIES OF SATURATED VAPOR OF SEVERAL REFRIGERANTS

Starr, Practical Refrigerating Engineers' Pocket Book, Nickerson & Collins Co.

TABLE XXIII.—CARBON BISULPHIDE—CS_2

Temp	Pressure		Volume Vapor	Density Vapor	Heat Content above 32° F		
	Absolute	Gage ins vac.			Liquid	Latent	Vapor*
°F	lb./in.²		ft.³/lb	ft./lb.³	Btu./lb	Btu./lb	Btu./lb
t	p	gp^*	V	$1/V$	h +	L =	H
0	1 10	27 7	53 76	0 0186	−8.60	165 5	156 90
5‡	**1 28**	**27 32**	**48 07**	**0 0208**	**—7.20**	**165 0**	**157 80**
10	1 46	26 95	43 47	0230	−5 60	164.5	158 90
15	1 67	26 52	38 91	0257	−4 40	164 0	159.60
20	1 89	26 07	34 84	0287	−3 00	163 2	160 20
25	2.11	25 63	32.10	0 0324	−1 82	162.9	161 08
30	2 36	25.11	29 49	0339	−0 50	162 2	161 70
35	2 47	24 89	28 32	0353	0 00	162 0	162 00
40	3 03	23.75	23 52	0425	+2 05	161 2	163 25
45	3 40	23 00	22 00	0454	2 40	160 7	163 10
50	3 90	21.95	20 60	0 0482	4.24	160.0	164 24
55	4 40	20 98	19 20	0521	5 80	159.8	165 60
60	4.95	19 84	18 00	0555	7.20	159.2	166 40
65	5 40	18 93	15 00	0666	8.50	158 8	167 30
70	5 85	18 03	13 20	0758	9 80	158.1	167 90
75	6.50	16 69	11 80	0874	10 80	157 5	165.30
80	7.30	15.07	10 40	0.0961	11.70	156.9	168.60
85	8 21	13 21	9.80	1020	12 60	156.2	168 80
86‡*	**8 40**	**12 82**	**9 15**	**.1058**	**12 84**	**156 1**	**168 94**
90	9 15	11 29	8 30	1204	13 80	155 6	169 40
95	10 00	9 54	7 60	1315	15 00	155.0	170 00
100	11 08	7.37	7 03	0 1369	16 15	154 4	170 55
105	12 30	4 89	6 40	1562	17 40	153 8	171.20
110	13 50	2 44	5 80	1724	18 30	153.2	171.50
114 5	14 70	0 00	5 45	1834	19 10	152 6	171.70
115	14 80	0 10†	5 40	1851	19 25	152 6	171 85
120	16 10	1 40†	5.10	0.1960	20.01	152 0	172 01

TABLE XXIV.—CARBON TETRACHLORIDE, $C\,Cl_4$

Temp	Pressure		Volume Vapor	Density Vapor	Heat Content above 32° F.		
	Absolute	Gage ins vac			Liquid	Latent	Vapor
°F	lb./in.²		ft.³/lb	ft./lb.³	Btu./lb.	Btu./lb	Btu./lb.
t	p	gp^*	V	$1/V$	h +	L =	H
20	0 40	29 1	69 5	0.01438	−2 00	94.45	92 45
25	56	28 8	61.0	01639	−1.20	94 00	92 80
30	60	28 7	53 0	01886	−0.25	93.70	93 45
32	64	28 6	52 6	01917	0 00	93.60	93.60
40	84	28 2	40.0	02500	+1 60	93 20	94 80
45	0 95	28 0	35 0	0.02857	2.58	92.90	95.48
52	1 07	27.7	34 0	.03113	3.58	92 60	96 18
55	1 25	27.4	27 0	03703	4.40	92 30	96 70
60	1 42	27.0	24.0	04166	5.95	92.20	98 15
65	1 60	26 7	21 5	04651	6 50	91 70	98 20
70	1 85	26.2	19.5	0.05128	8.20	91.40	99.60
75	2 15	25.5	17 5	05714	8.50	91.05	99 55
80	2.40	25.0	16.0	.06345	9.80	90.07	99 87
85	2.70	24.4	14.5	06896	10.60	90 04	100 64
86 ‡*	**2 78**	**24 2**	**14 2**	**07037**	**10 80**	**90 04**	**100 83**
90	3.12	23 5	13 0	07692	11 60	90 02	101 62
95	3.60	22 6	11.0	0.0909	12.40	89 70	102.10
100	4 00	21.8	10.0	.1000	13.40	89 40	102.80
105	4 42	20 9	9 0	1111	14 60	89 20	103.80
110	4.89	20.1	8 5	1176	15 80	88 70	104.50
115	5.35	19.1	8 0	1250	16 95	88 30	105.25
120	5.95	17.8	7 5	0.1333	18.06	87.90	105.90
125	6 50	16.7	7 0	1428	18.90	87 50	106 40
130	7 20	15 2	6 3	1587	19.95	87.10	107.05
135	7 90	13.9	5 5	1818	20 99	86 70	107 69
140	8 65	12 3	4 8	2066	21 46	86 32	107.78
170	14 70	0	2.8	0.3571	26 90	83 00	109 90

TABLE XXV.—CHLOROFORM—$CH\,Cl_3$

t	p	gp^*	V	$1/V$	h	L	H^*
20	0 08	29 76	50.00	0.02012	−4.00	121 60	117 60
25	1.00	27 83	44.00	.0227	−2.5	120 20	117 70
32	1.15	27.58	38 10	02626	0 00	120 60	120 60
50	2 03	25.79	23.65	04232	4 19	118 87	123.06
68	3.15	23.51	18 50	06505	8 40	117 14	125 54
86†	**4.80**	**20 15**	**10.50**	**0 0952**	**12 63**	**115 38**	**128 01**
104	7.52	14 61	7 14	1403	16 86	113 63	130.49
122	10.30	8 96	5 06	1979	20 13	111 83	131 96
140.5	14.70	0 00	4.95	2200	23 70	109 00	132 70

TABLE XXVI.—ETHYL ETHER[2]—$(C_2H_5)_2O$

t	p	gp	V	$1/V$	h	L	H^*
0	1 3	27.28	38.0	0.0263	−18.00	171.0	153 00
5‡	**1 5**	**26 87**	**35 0**	**0285**	**−15 00**	**170 8**	**155 80**
10	1.8	26 26	32.5	.0352	−12.00	170 4	158.43
15	2.2	25 46	30.0	0332	−9.50	170.2	161.70
20	2.5	24.84	27.0	.0372	−6.50	170.0	163 50
25	2.9	24 03	24.3	0.0417	−4.00	169.6	165.60
30	3 4	23 00	21.4	.0468	−1.50	169.4	167.90
35	3.9	22 00	19.3	0518	+1.40	168.8	170.20
40	4.4	21 09	17.0	.0588	4.00	168.4	172.40
45	4.9	19 97	15.0	.0666	6.60	168.0	174.60
50	5.5	18.72	13.2	0.0757	9.57	167.6	177.17
70	8.8	12 05	7.8	.1280	20 04	165.4	185 44
75	9 8	10.02	7.0	.1430	23.40	164 8	188.20
80	10 9	7 33	6 2	1620	26.40	164 2	190 60
85	12.2	5.09	5 5	1860	29.00	163 8	192 80
86*‡	**12 3**	**4.62**	**5 4**	**1880**	**29.50**	**163 5**	**193 00**
90	13.4	2.72	5.1	0.1960	31.50	163.0	194.50
95	14 7	0 00	4 8	.2130	34 00	162.2	196 20
100	16 0	1.3†	4.5	2220	36 50	161 5	197 50

TABLE XXVII.—NITROUS OXIDE—N_2O

Temp.	Pressure		Volume		Density		Heat Latent
	Absolute	Gage	Liquid	Vapor	Liquid	Vapor	
°F	lb./in.²	lb./in.²	ft.³/lb.	ft.³/lb.	lb./ft.³	lb./ft.³	Btu./lb.
t	p	gp^*	v	V	$1/v^*$	$1/V$	L
−130	14.2	0 5	0.01232	5.940	81.17	0.165	162.3
−121	19.6	4 9	.01248	4.370	80.13	23	168.9
−112	26 8	12 0	.01264	3.200	79.11	.30	165.6
−103	35.5	20 8	.01280	2.480	78.12	.40	162.3
−94	47.3	32.6	.01296	1.880	77.16	.53	158.9
−85	59.6	44.9	0.01312	1.510	76.22	0.66	155.0
−76	75.0	60.3	.01314	1.220	76.10	0.82	150.7
−67	92.3	77.6	.01376	0.9990	72.67	1.00	148.9
−58	113.0	98 3	.01408	.8270	71.02	1.20	145.8
−49	135.0	120 3	.01440	.6960	69.44	1.40	142.5
−40	160.0	145.3	0.01472	0.6000	67.93	1.65	139.1
−31	190.0	175.3	.01504	.5120	66.49	1.95	135.6
−22	223.0	208.3	.01536	.4430	65.10	2.25	132.3
−13	257.0	242.3	.01568	3950	63 77	2.50	129.0
−4	295.0	280.3	.01600	.3470	62 50	2.85	125 2
‡+5	**333.0**	**318.3**	**0.01632**	**0.3080**	**61.27**	**3 25**	**121 4**
14	375.0	360.3	.01680	.2690	59.52	3.70	116.8
23	422.0	405.3	.01728	.2340	57 87	4.25	111.9
32	471.0	456.3	.01776	.2017	56.30	4.95	107 5
41	528.0	513.3	.01845	.1744	54.19	5.70	103.2
50	592.0	577.3	0.01920	0.1496	52.08	6.65	95.8
59	663.0	648.3	.02016	.1276	45.60	7.80	88 2
68	745.0	730.3	.02140	1076	46.73	9.30	73.6
77	832 0	817.3	.02300	.0896	43.48	11.20	66 9
‡86	**930.0**	**915.3**	**02560**	**0726**	**39 06**	**13 80**	**51 1**
95	1035.0	1020.3	0.03136	0.0634	31.88	18.70	24.4
96	1055.0	1040.3	.03498	.0537	28.58	23.50	13.2
97	1065 0	1040.3	.04080	.0408	24 51	24 50	0 0

TABLE XXVIII.—PROPERTIES OF SATURATED VAPOR OF ETHANE—C_2H_6
(H. D. Edwards)

Temp. °F t.	Pressure Abs. lb./in.² p.	Pressure Gage lb./in.² g.p.	Specific Volume Liquid ft.³/lb. v	Specific Volume Vapor ft.³/lb. V	Density Liquid lb./ft.³ 1/v	Density Vapor lb./ft.³ 1/V	Heat Content Above—40° Latent Btu./lb.;L=	Temp °F t.
-150	7.0	*15.6	0.02849	16.7	35.10	0.060	242	-150
-145	8.0	*13.6	0.02865	14.1	34.90	0.071	240	-145
-140	9.7	*10.1	0.02888	12.1	34.63	0.083	238	-140
-135	11.2	* 7.1	0.02901	10.5	34.47	0.095	236	-135
-130	13.2	* 3.0	0.02924	8.85	34.20	0.113	235	-130
-125	15.5	0.8	0.02939	1.69	34.02	0.130	233	-125
-120	18.2	3.5	0.02961	6.89	33.77	0.145	231	-120
-115	21.4	6.7	0.02976	5.88	33.60	0.170	229	-115
-110	24.8	10.1	0.03001	5.27	33.32	0.190	227	-110
-105	28.5	13.8	0.03018	4.55	33.13	0.220	225	-105
-100	32.4	17.7	0.0305	4.13	32.8	0.242	224	100
-95	36.4	21.7	0.0307	3.57	32.6	0.280	222	-95
-90	41.0	26.3	0.0309	3.23	32.4	0.310	220	-90
-85	46.0	31.3	0.0311	2.86	32.2	0.350	218	-85
-80	51.2	36.5	0.0313	2.56	31.9	0.390	216	-80
-75	56.8	42.1	0.0315	2.35	31.7	0.425	214	-75
-70	63.0	48.3	0.0318	2.10	31.5	0.477	212	-70
-65	70.3	55.6	0.0320	1.94	31.3	0.515	210	-65
-60	78.2	63.5	0.0322	1.75	31.0	0.570	208	-60
-55	80.6	75.9	0.0325	1.63	30.8	0.615	206	-55
-50	95.9	81.2	0.0327	1.50	30.5	0.666	204	-50
-45	105.0	90.3	0.0330	1.39	30.3	0.720	201	-45
-40	114.5	99.8	0.0333	1.28	30.0	0.780	199	-40
-35	124.5	109.8	0.0336	1.18	29.8	0.845	196	-35
-30	135.0	120.3	0.0339	1.13	29.5	0.875	194	-30
-25	146.7	132.0	0.0342	1.05	29.2	0.950	192	-25
-20	159.5	144.8	0.0345	0.976	28.9	1.03	190	-20
-15	172	157	0.0350	0.855	28.6	1.17	187	-15
-10	187	172	0.0353	0.819	28.3	1.22	185	-10
-5	202	187	0.0357	0.730	28.0	1.37	182	-5
0	219	204	0.0361	0.689	27.7	1.45	179	0
+5	236	221	0.0365	0.629	27.4	1.59	176	+5
+10	254	239	0.0370	0.581	27.0	1.72	174	+10
+15	272	257	0.0375	0.538	26.7	1.86	171	+15
+20	292	277	0.0379	0.495	26.3	2.02	168	+20
+25	307	292	0.0385	0.457	26.0	2.19	165	+25
+30	335	320	0.0390	0.422	25.6	2.37	162	+30
+35	358	343	0.0397	0.389	25.2	2.57	158	+35
+40	383	368	0.0403	0.360	24.8	2.78	155	+40
+45	405	390	0.0410	0.330	24.4	3.03	150	+45
+50	428	413	0.0417	0.305	24.0	3.28	146	+50
+55	453	438	0.0426	0.279	23.5	3.58	141	+55
+60	481	466	0.0435	0.256	23.0	3.90	136	+60
+65	511	496	0.0444	0.238	22.5	4.20	130	+65
+70	543	528	0.0461	0.214	21.7	4.67	124	+70
+75	584	569	0.0478	0.182	20.9	5.50	115	+75
+80	625	610	0.0508	0.163	19.7	6.14	107	+80
+85	672	657	0.0549	0.128	18.2	7.80	78	+85
+89.8	718	703	0.0775	0.0775	12.9	12.9	0	+89.8

* Inches of mercury below one standard atmosphere (29.92 in.=14.697 lbs./sq. in. abs.)

NOTE:—References: Vapor Pressures. From 7 to 32 lbs./sq. in. abs. by Maass & Wright, J. Am. Chem. Soc., 43, p. 1098, 1921. From 31 to 347 lbs./sq. in. abs. by Kuenen and Robson, Phil. Mag, (6) 3, p. 149, 1902. From 162 to 734 lbs./sq. in. abs. A. Hainlen, Lieb. Ann, 282, p. 229, 1894. Liquid and Vapor Densities. From—162° F. to—101° F. experimental data on liquid by Maass & Wright, J. Am. Chem. Soc., 43, p. 1104, 1921. Remainder of liquid and all of Vapor data as well as latent heats, calculated by The Laboratory of The Linde Air Products Co., Buffalo, N. Y. Probable accuracy of Density, Liquids, 1%; Vapor, 3%; Latent Heats, 10%.

TABLE XXIX. -PROPERTIES OF SATURATED VAPOR OF ETHYL CHLORIDE C_2H_5Cl.

Hodsdon, 1919. Refrigerating World, Aug., (1922). Henning, Ohnes, Regnault and others; compiled by Starr. Practical Refrigerating Engineers' Hand Book, Nickerson & Collins Co., Chicago, 1922.

Tem	Pressure		Volume		Density		Heat Content Above — 32°F.		
°F.	Abs. lb./in.²	Gage lb./in.²	Liquid ft.³/lb.	Vapor ft.³/lb.	Liquid lb./ft.³	Vapor lb./ft.³	Liquid Btu./lb.	Latent Btu./lb.	Vapor Btu./lb.
t	*p*	*g p*	*v*	*V*	*1/v*	*1/V*	*h*+	*L*=	*H*
−22	2.20	−12.5	0.01657	34.4	60.35	0.0291	−23.1	181.3	158.2
−13	2.85	−11.85	.01669	26.95	59.92	.0371	−19.2	179.9	160.7
− 4	3.66	−11.04	.01682	21.33	59.45	.0469	−15.4	178.5	163.1
+‡5	**4.65**	**−10.05**	**.01695**	**17.06**	**59.00**	**.0586**	**−11.6**	**177.0**	**165.4**
14	5.85	− 8.85	.01708	13.77	58.55	.0726	− 7.7	175.5	167.8
23	7.28	− 7.42	0.01721	11.21	58.10	0.0892	− 3.8	174.0	170.2
32	8.99	− 5.71	.01735	9.21	57.64	.1086	0.0	172.5	172.5
41	11.01	− 3.69	.01749	7.62	57.18	.1311	+ 3.8	170.9	174.7
50	13.37	− 1.33	.01763	6.36	56.72	.1573	7.7	169.3	177.0
59	16.11	+ 1.41	.01777	5.34	56.27	.1873	11.6	167.7	179.3
68	19.29	4.50	0.01792	4.51	55.80	0.2215	15.4	166.0	181.4
77	22.94	8.24	.01807	3.84	55.34	.2604	19.2	164.3	183.5
‡86	**27.10**	**12.40**	**.01822**	**3.29**	**54.88**	**.3043**	**23.1**	**162.6**	**185.7**
95	31.82	17.12	.01838	2.83	54.41	.3536	26.9	160.8	187.7
104	37.17	22.47	0.01854	2.44	53.94	0.4090	30.8	159.0	189.9
113	43.16	28.46	.01870	2.13	53.47	.4704	34.6	157.2	191.8
122	49.88	35.18	.01887	1.86	53.00	.5382	38.5	155.3	193.8
131	57.36	42.66	.01904	1.63	52.52	.6135	42.3	153.3	195.6
−22	2.13	−12.57	0.0163	34.2	61.5	0.029	−23.1	193.0	170.0
−13	2.80	−11.90	.0164	26.5	61.0	.038	−19.2	192.0	172.5
− 4	3.63	−11.07	.0164	20.9	60.6	.048	−15.4	191.0	175.5
+‡5	**4.63**	**−10.07**	**.0167**	**16.7**	**60.1**	**.061**	**−11.5**	**190.0**	**178.5**
14	5.84	− 8.86	.0169	13.5	59.7	.074	− 7.7	188.5	181.0
23	7.28	− 7.42	0.0169	11.0	59.2	0.091	3.85	187.5	183.5
32	9.00	− 5.70	.0170	9.1	58.8	.110	0	186.0	186.0
41	11.00	− 3.70	.0172	7.6	58.3	.132	+ 3.85	184.5	188.0
50	13.55	− 1.15	.0174	6.25	57.9	.160	7.7	182.5	190.0
54.5	**14.70**	**0.00**	**.0175**	**5.6**	**57.6**	**0.179**	**9.52**	**181.5**	**191.5**
59	16.10	+ 1.40	0.0176	5.35	57.3	0.187	11.5	180.5	192.5
68	19.26	4.56	.0176	4.55	56.9	.220	15.4	179.5	194.0
77	22.90	8.20	.0177	3.90	56.5	.256	19.2	176.5	196.0
‡86	**27.05**	**12.35**	**.0178**	**3.35**	**56.0**	**.299**	**23.1**	**174.0**	**197.5**
95	31.77	17.07	.0180	2.89	55.6	.345	27.0	172.0	199.0
104	37.11	22.41	0.0182	2.57	55.1	0.374	30.8	169.0	200.0

Gage pressures table supplied by Editor A. S. R. E. Data Book.
‡Standard ton temperatures.

TABLE XXX.—PROPERTIES OF SATURATED VAPOR OF ISOBUTANE—C_4H_{10}

Linde Air Products Company Laboratory. Refrigeration Engineering, June, 1926. *A. S. R. E. Data Book.*

Temp.	Pressure		Volume		Density		Heat Content Above 0° F.			Entropy From 0° F.		Temp.
° F.	Abs. lb./in.²	Gage lb./in.²	Liquid ft.³/lb.	Vapor ft.³/lb.	Liquid lb./ft.³	Vapor lb./ft.³	Liquid Btu./lb.	Latent Btu./lb.	Vapor Btu./lb.	Liquid Btu./lb.°F.	Vapor Btu./lb.°F.	° F.
t	p	gp	v	V	$1/v$	$1/V$	h +	L =	H	s	S	t
−20	7.50	14.6*	0.02610	11.00	38.35	0.0952	−9.0	165.5	156.5	−0.020	0.356	**−20**
−15	8.30	13.0*	.02620	9.90	38.15	.101	−7.0	164.0	157.0	−0.015	.354	−15
−10	9.28	11.0*	.02635	8.91	37.95	.112	−4.5	163.0	158.5	−0.010	.353	−10
− 5	10.4	8.8*	.02645	7.99	37.80	.125	−2.5	162.0	159.5	−0.005	.351	− 5
0	11.6	6.3*	0.02660	7.17	37.60	0.139	0.0	160.5	160.5	0.000	0.350	**0**
+ 1	11.9	5.7*	.02663	7.02	37.55	.142	0.5	160.5	161.0	.001	.350	+ 1
2	12.2	5.1*	.02667	6.87	37.50	.146	+1.0	160.0	161.0	.002	.350	2
3	12.5	4.5*	.02670	6.72	37.46	.149	1.5	160.0	161.5	.003	.350	3
4	12.8	4.0*	.02672	6.57	37.43	.152	2.0	159.5	161.5	.004	.350	4
5‡	**13.1**	**3.3***	**0.02675**	**6.41**	**37.40**	**0.156**	**2.5**	**159.5**	**162.0**	**0.005**	**0.348**	**5‡**
6	13.3	2.7*	.02677	6.28	37.35	.159	3.0	159.0	162.0	.006	.349	6
7	13.6	2.1*	.02680	6.15	37.31	.163	3.5	159.0	162.5	.007	.349	7
8	13.9	1.5*	.02683	6.02	37.27	.166	4.0	158.5	162.5	.009	.349	8
9	14.2	0.9*	.02686	5.88	37.23	.170	4.5	158.5	163.0	.010	.349	9
10	14.6	0.2*	0.02690	5.75	37.20	0.174	5.0	158.5	163.5	0.011	0.348	**10**
11	14.8	0.1	.02692	5.65	37.15	.177	5.5	158.0	163.5	.012	.348	11
12	15.2	0.5	.02695	5.52	37.11	.181	6.0	158.0	164.0	.013	.348	12
13	15.6	0.9	.02698	5.41	37.07	.185	6.5	157.5	164.0	.014	.348	13
14	15.9	1.2	.02700	5.30	37.04	.190	7.0	157.5	164.5	.015	.348	14
15	16.3	1.6	0.02705	5.18	37.00	0.193	7.5	157.0	164.5	0.016	0.347	**15**
16	16.7	2.0	.02706	5.08	36.96	.197	8.0	157.0	165.0	.017	.347	16
17	17.0	2.3	.02709	4.98	36.92	.201	8.5	156.5	165.0	.018	.347	17
18	17.4	2.7	.02711	4.88	36.88	.205	9.0	156.5	165.5	.019	.347	18
19	17.8	3.1	.02714	4.78	36.84	.209	9.5	156.0	165.5	.020	.347	19
20	18.2	3.5	0.02717	4.68	36.80	0.214	10.0	156.0	166.0	0.021	0.346	**20**
21	18.6	3.9	.02720	4.59	36.76	.218	10.5	155.5	166.0	.022	.346	21
22	19.0	4.3	.02723	4.50	36.72	.222	11.0	155.5	166.5	.023	.346	22
23	19.4	4.7	.02726	4.41	36.68	.227	11.5	155.5	167.0	.025	.346	23
24	19.8	5.1	.02729	4.32	36.64	.231	12.5	154.5	167.0	.026	.346	24
25	20.2	5.5	0.02730	4.24	36.60	0.236	13.0	154.5	167.5	0.027	0.346	**25**
26	20.6	5.9	.02735	4.15	36.56	.241	13.5	154.0	167.5	.028	.346	26
27	21.0	6.3	.02737	4.07	36.53	.246	14.0	154.0	168.0	.029	.346	27
28	21.5	6.8	.02741	4.00	36.48	.250	14.5	154.0	168.5	.030	.346	28
29	21.9	7.2	.02744	3.93	36.44	.254	15.0	153.5	168.5	.031	.346	29
30	22.3	7.6	0.02745	3.86	36.40	0.259	15.5	153.5	169.0	0.032	0.346	**30**
35	24.6	9.9	.02760	3.52	36.20	.284	18.0	152.5	170.5	.038	.346	35
40	26.9	12.2	.02780	3.22	36.00	.311	21.0	151.0	172.0	.044	.346	40
45	29.5	14.8	.02795	2.96	35.80	.338	24.0	150.0	174.0	.049	.346	45
50	32.5	17.8	.02810	2.71	35.60	.369	27.0	148.5	175.5	.055	.346	50
55	35.5	20.8	0.02825	2.49	35.40	0.402	30.0	147.5	177.5	0.061	0.347	**55**
60	38.7	24.0	.02840	2.28	35.20	.439	33.0	146.0	179.0	.067	.348	60
65	42.2	27.5	.02855	2.10	35.00	.476	36.5	144.5	181.0	.073	.349	65
70	45.8	31.1	.02875	1.94	34.80	.515	39.5	143.5	183.0	.079	.350	70
75	49.7	35.0	.02890	1.79	34.60	.559	43.0	142.0	185.0	.086	.351	75
80	53.9	39.2	0.02910	1.66	34.35	0.602	46.5	140.5	187.0	0.092	0.352	**80**
85	58.6	43.9	.02930	1.54	34.10	.649	50.0	139.0	189.0	.098	.353	85
86‡	**59.5**	**44.8**	**.02935**	**1.52**	**34.10**	**.658**	**50.5**	**139.0**	**189.5**	**.099**	**.354**	**86‡**
90	63.3	48.6	.02950	1.42	33.90	.704	53.5	137.5	191.0	.105	.356	90
95	68.4	53.7	.02965	1.32	33.70	.758	57.5	136.0	193.5	.112	.358	95
100	73.7	59.0	0.02990	1.23	33.45	0.813	61.0	134.5	195.5	0.118	0.359	**100**
105	79.3	64.6	.03005	1.14	33.25	.877	65.0	133.0	198.0	.125	.360	105
110	85.1	70.4	.03030	1.07	33.00	.935	69.0	131.0	200.0	.132	.362	110
115	91.4	76.7	.03050	0.990	32.80	1.01	73.0	129.5	202.5	.139	.364	115
120	98.0	83.3	.03075	.926	32.50	1.08	77.0	127.5	204.5	.147	.367	120
125	104.8	90.1	0.03095	0.867	32.30	1.15	81.5	126.0	207.5	0.154	0.369	**125**
130	112.0	97.3	.03125	.811	32.00	1.23	86.0	124.0	210.0	.161	.371	130
135	119.3	104.6	.03145	.760	31.80	1.32	90.5	122.0	212.5	.169	.375	135
140	126.8	112.1	.03175	.716	31.50	1.40	95.0	120.5	215.5	.176	.377	140

* Inches of Mercury below one standard atmosphere (29.82 in. = 14.696 lbs./sq. in. abs.)
‡Standard Ton Temperatures

TABLE XXXI.—SATURATED METHYL CHLORIDE (CH_3 Cl) VAPOR

Calculated in English Units by Starr from work of Ohnes and Holst.

"Practical Refrigerating Engineers' Pocketbook" Published by Nickerson & Collins Co., Chicago.

Temp. Deg. Fahr.	Abs. Press. Lbs. per Sq. In.	Heat Content of Liquid	Heat of Vaporization	Spec. Vol. Cu. Ft. per Lb.	Density Lbs. per Cu. Ft.
−40	6.96	−34.0	183.3	12.57	0.07955
−35	7.60	−31.5	183.0	11.00	0.0909
−30	9.00	−29.0	182.6	9.70	0.103
−25	10.20	−26.7	182.0	8.60	0.1162
−20	11.80	−24.5	181.4	7.80	0.1282
−15	13.00	−22.3	180.9	7.00	0.1428
−10	15.10	−20.0	180.3	6.25	0.1600
− 5	16.80	−17.5	180.0	5.60	0.1785
0	18.00	−15.1	179.2	5.05	0.1980
5	20.70	−12.8	178.3	4.53	0.2207
10	23.00	−10.2	177.8	4.15	0.2409
15	24.90	− 8.0	177.03	3.70	0.2702
20	28.50	− 5.6	176.05	3.25	0.3076
25	32.00	− 3.2	175.8	2.90	0.3448
30	35.00	− 1.6	174.8	2.71	0.3690
32	36.62	0.0	174.6	2.67	0.3745
40	42.90	+ 3.7	173.0	2.25	0.4444
50	46.50	+ 8.5	171.0	1.94	0.5154
60	62.00	+13.2	169.0	1.62	0.9803
65	68.00	15.5	167.85	1.50	0.6666
70	73.10	17.8	166.8	1.39	0.7194
75	80.00	20.2	165.6	1.27	0.7842
80	87.00	22.5	164.2	1.15	0.8695
85	94.30	25.0	163.0	1.05	0.9523
90	104.00	27.2	161.6	0.995	1.0051
95	110.10	29.6	160.4	0.938	1.0661
100	119.50	31.8	158.8	0.855	1.1695
110	137.50	36.3	156.1	0.77	1.2987

NOTE.—To get gauge pressures 14.7 lbs. are subtracted from the absolute pressures given in the tables. When the absolute pressure is below 14.7 lb. the absolute pressure is subtracted from 14.7 lbs. and this result is multiplied by 2.0355 (for approximate results, 2.0 may be used). This gives the vacuum in inches of mercury below the atmospheric pressure of 14.7 lbs.

TABLE XXXII.—PROPERTIES OF SATURATED VAPOR OF PROPANE—C_3H_8

Linde Air Products Company Laboratory. Refrigeration Engineering, June 1926.
A. S. R. E. Data Book.

Temp.	Pressure		Volume		Density		Heat Content Above 0° F			Entropy From 0° F.		Temp.
° F	Abs. lb./in.²	Gage lb./in.²	Liquid ft.³/lb.	Vapor ft.³/lb.	Liquid lb./ft.³	Vapor lb./ft.³	Liquid Btu./lb.	Latent Btu./lb	Vapor Btu./lb	Liquid Btu./lb °F	Vapor Btu./lb °F	° F.
t	p	gp	v	V	$1/v$	$1/V$	h +	L =	H	s	S	t
−75	6.37	17.0*	0 02660	14.5	37.59	0 0690	−39 5	190 5	151 0	−0 092	0 404	**−75**
−70	7.37	14.9*	02674	12 9	37.40	0775	−37.0	189 5	152 5	−0.086	400	−70
−65	8.48	12 7*	02688	11 3	37 20	0885	−34.5	188 0	153 5	−0.080	397	−65
−60	9 72	10.1*	02703	9 93	37 00	111	−32.0	187 0	155 0	−0 074	.393	−60
−55	11 1	7.3*	02717	8 70	36.80	115	−29.0	185.5	156 5	−0 067	391	−55
−50	12.6	4.3*	0.02732	7.74	36.60	0 129	−26.5	184.5	158.0	−0 061	0 389	**−50**
−45	14.4	0 6*	02748	6.89	36 39	145	−24.0	183 0	159 0	−0 055	386	−45
−40	16.2	1 5	02763	6.13	36.19	163	−21.5	181 5	160 0	−0 049	384	−40
−35	18 1	3 4	02779	5 51	35 99	181	−19 0	180 0	161 0	−0 042	382	−35
−30	20 3	5.6	02795	4 93	35.78	203	−16.0	179.0	163 0	−0 036	380	−30
−25	22 7	8 0	0 02811	4.46	35.58	0.224	−13.5	177.5	164.0	−0 030	0 378	**−25**
−20	25 4	10 7	02827	4 00	35.37	250	−11.0	176 0	165 0	−0 024	377	−20
−15	28 3	13 6	02844	3.60	35.16	278	− 8.0	175 0	167 0	−0 018	375	−15
−10	31 4	16 7	02860	3 26	34.96	307	− 5.5	173 5	168 0	−0 012	374	−10
− 5	34 7	20 0	02878	2 97	34 75	337	− 2.5	172 0	169 5	−0 006	372	− 5
0	38.2	23.5	0 02895	2.71	34.54	0.369	0.0	170.5	170.5	0 000	0.371	**0**
+ 1	39 0	24.3	02899	2.66	34.49	376	0.5	170 5	171 0	001	371	+ 1
2	39 7	25 0	02903	2 61	34 45	383	1 0	170 5	171 5	002	.371	2
3	40.5	25.8	02906	2.57	34.41	389	1 5	170 0	171 5	003	371	3
4	41 3	26 6	02910	2 52	34.37	396	2.0	170 0	172 0	004	371	4
5‡	**42.1**	**27.4**	**0 02913**	**2.48**	**34 33**	**0 403**	**+ 3.0**	**169 5**	**172 0**	**+0 006**	**0.370**	**5‡**
6	42.9	28 2	02916	2.43	34 29	411	3.5	169 0	172 5	007	.370	6
7	43.7	29 0	02920	2.39	34 25	418	4 0	168 5	172 5	008	370	7
8	44 5	29 8	02924	2.35	34.20	426	4.5	168 5	173 0	009	370	8
9	45 3	30 6	02927	2.31	34 16	433	5.0	168 0	173 0	010	370	9
10	46.1	31.4	0 02931	2.27	34 12	0.441	5.5	168 0	173 5	0 012	0 370	**10**
11	47.0	32 3	02935	2.23	34 07	448	6.0	168 0	174 0	013	370	11
12	47.9	33.2	02939	2.19	34 03	456	6.5	167 5	174 0	014	370	12
13	48 8	34.1	02943	2.15	33 98	465	7.5	167 0	174.5	015	370	13
14	49 7	35 0	02946	2 11	33 94	474	8.0	166 5	174.5	016	370	14
15	50 6	35 9	0 02950	2 07	33 90	0 483	8.5	166.5	175 0	0 018	0 369	**15**
16	51 6	36 9	02954	2 04	33 85	491	9.0	166 0	175 0	019	369	16
17	52 5	37 8	02959	2 00	33 80	500	9.5	166 0	175.5	.020	369	17
18	53 5	38 8	02963	1.97	33 75	.509	10 0	165 5	175 5	021	369	18
19	54.5	39 8	02966	1.93	33 71	518	10.5	165.5	176 0	022	369	19
20	55 5	40 8	0 02970	1.90	33.67	0.526	11.0	165.0	176 0	0.024	0 368	**20**
25	60 9	46 2	02991	1 74	33 43	575	14.0	163 5	177.5	030	.368	25
30	66 3	51 6	03012	1.60	33.20	625	17.0	162 0	179 0	.035	366	30
35	72 0	57 3	03033	1 48	32 97	.676	20.0	160 5	180 5	041	.366	35
40	78 0	63 3	03055	1 37	32 73	730	23.0	159.0	182 0	047	366	40
45	84 6	69 9	0 03078	1.27	32 49	0.787	26.0	157.5	183.5	0 053	0.365	**45**
50	91 8	77 1	03102	1 18	32 24	.847	29.0	156 0	185 0	059	.365	50
55	99 3	84 6	03125	1.10	32 00	909	32.0	154 5	186 5	.065	365	55
60	107 1	92.4	03150	1.01	31.75	990	35.0	153 0	188 0	070	.364	60
65	115 4	100 7	03174	0.945	31.50	1 06	38.0	151 5	189.5	.076	.364	65
70	124 0	109 3	0 03201	0.883	31.24	1.13	41.0	149 5	190 5	0 082	0.364	**70**
75	133 2	118 5	03229	825	30 97	1 21	44.0	148 0	192 0	088	364	75
80	142 8	128 1	03257	.770	30.70	1 30	47.5	146 0	193 5	093	.364	80
85	153 1	138 4	03287	722	30.42	1 39	50.5	144 5	195 0	099	.364	85
86‡	**155 3**	**140 5**	**03292**	**717**	**30 38**	**1 40**	**51.0**	**144 0**	**195 0**	**100**	**364**	**86‡**
90	164 0	149 0	0 03317	0.673	30.15	1 49	54.0	142.5	196.5	0 105	0.364	**90**
95	175 0	160 0	03348	.632	29.87	1.58	57.0	140 5	197 5	111	364	95
100	187 0	172 0	03381	591	29 58	1.69	60.5	138 5	199.0	116	363	100
105	200 0	185 0	03416	553	29 27	1 81	63.5	136 5	200 0	122	363	105
110	212 0	197 0	03453	520	28 96	1 92	67 0	134 0	201 0	128	363	110
115	226 0	211 0	0 03493	0.488	28.63	2 05	70.5	131.5	202 0	0.134	0 363	**115**
120	240 0	225 0	03534	459	28.30	2 18	73 5	129 0	202 5	.140	.363	120
125	254 0	239 0	03575	432	27 97	2 31	77.0	126 5	203 5	.145	361	125

* Inches of Mercury below one standard atmosphere (29 82 in. = 14,696 lbs./sq in abs.)
‡ Standard Ton Temperatures

TABLE XXXIII.—PROPERTIES OF SATURATED VAPOR OF SULPHUR DIOXIDE—SO_2

David L. Fiske, Urbana, Ill.—1925. A. S. R. E. Data Book.

Tem.	Pressure		Volume		Density		Heat Content Above − 40°		
°F. t	Abs. lb./in.² p	Gage lb./in.² $g\ p$	Liquid ft.³/lb. v	Vapor ft.³/lb. V	Liquid lb./ft.³ $1/v$	Vapor lb./ft.³ $1/V$	Liquid Btu./lb. $h+$	Latent† Btu./lb. $L=$	Vapor Btu./lb. H
−40	3.136	23.54*	0.010440	22.42	95.79	0.04460	0.00	178.61	178.61
−35	3.693	22.41*	.010486	19.23	95.36	.05200	1.45	177.82	179.27
−30	4.331	21.10*	.010532	16.56	94.94	.06039	2.93	176.97	179.90
−25	5.058	19.63*	0.010580	14.31	94.52	0.06988	4.44	176.06	180.50
−20	5.883	17.93*	.010627	12.42	94.10	.08119	5.98	175.09	181.07
−15	6.814	16.05*	.010674	10.81	93.68	.09250	7.56	174.06	181.62
−10	7.863	13.91*	.010721	9.44	93.27	.1025	9.16	172.97	182.13
− 5	9.038	11.52*	.010770	8.28	92.85	.1208	10.79	171.83	182.62
0	10.35	8.85*	0.010820	7.280	92.42	0.1374	12.44	170.63	183.07
1	10.63	8.27*	.010830	7.099	92.33	.1408	12.79	170.38	183.17
2	10.91	7.34*	.010840	6.923	92.25	.1444	13.12	170.13	183.25
3	11.20	7.11*	.010850	6.751	92.16	.1481	13.45	169.88	183.33
4	11.50	6.50*	.010860	6.584	92.08	.1591	13.78	169.63	183.41
5‡	**11.81**	5.87*	**0.010870**	**6.421**	**92.00**	**0.1558**	**14.11**	**169.38**	**183.49**
6	12.12	5.24*	.010880	6.266	91.91	.1596	14.45	169.12	183.57
7	12.43	4.61*	.010890	6.114	91.83	.1628	14.79	168.86	183.65
8	12.75	3.96*	.010900	5.967	91.74	.1676	15.13	168.60	183.73
9	13.08	3.29*	.010910	5.822	91.66	.1717	15.46	168.34	183.80
10	13.42	2.59*	0.010920	5.682	91.58	0.1760	15.80	168.07	183.87
11	13.77	1.88*	.010930	5.548	91.49	.1803	16.14	167.80	183.94
12	14.12	1.17*	.010940	5.417	91.41	.1846	16.48	167.53	184.01
13	14.48	0.44*	.010950	5.289	91.33	.1890	16.81	167.26	184.07
14	14.84	.14	.010960	5.164	91.24	.1936	17.15	166.97	184.14
15	15.21	.51	0.010971	5.042	91.16	0.1983	17.49	166.72	184.21
16	15.59	.89	.010981	4.926	91.07	.2030	17.84	166.44	184.28
17	15.98	1.28	.010992	4.812	90.98	.2078	18.18	166.16	184.34
18	16.37	1.67	.011003	4.701	90.89	.2127	18.52	165.88	184.40
19	16.77	2.07	.011014	4.593	90.80	.2177	18.86	165.60	184.46
20	17.18	2.48	0.011025	4.487	90.71	0.2228	19.20	165.32	184.52
21	17.60	2.90	.011036	4.386	90.62	.2280	19.55	165.03	184.58
22	18.03	3.33	.011047	4.287	90.53	.2332	19.90	164.74	184.64
23	18.46	3.76	.011058	4.190	90.44	.2387	20.24	164.45	184.69
24	18.89	4.19	.011070	4.096	90.33	.2441	20.58	164.16	184.74
25	19.34	4.64	0.011082	3.994	90.24	0.2404	20.92	163.87	184.79
26	19.80	5.10	.011093	3.915	90.15	.2559	21.26	163.58	184.84
27	20.26	5.56	.011104	3.829	90.06	.2611	21.61	163.28	184.89
28	20.73	6.03	.011116	3.744	89.96	.2671	21.96	162.98	184.94
29	21.21	6.51	.011128	3.662	89.86	.2731	22.30	162.68	184.98
30	21.70	7.00	0.011140	3.581	89.76	0.2800	22.64	162.38	185.02
31	22.20	7.50	.011152	3.503	89.67	.2854	22.98	162.08	185.06
32	22.71	8.01	.011164	3.437	89.58	.2909	23.33	161.77	185.10
33	23.23	8.53	.011176	3.355	89.48	.2980	23.68	161.46	185.14
34	23.75	9.05	.011188	3.283	89.39	.3046	24.03	161.15	185.18
35	24.28	9.58	0.011200	3.212	89.29	0.3113	24.38	160.84	185.22
36	24.82	10.12	.011212	3.144	89.18	.3181	24.72	160.53	185.25
37	25.39	10.69	.011224	3.078	89.09	.3249	25.07	160.21	185.28
38	25.95	11.25	.011236	3.013	89.00	.3319	25.42	159.89	185.31
39	26.52	11.82	.011248	2.949	88.90	.3391	25.77	159.57	185.34
40	27.10	12.40	0.011260	2.887	88.81	0.3464	26.12	159.25	185.37
41	27.69	12.99	.011272	2.827	88.71	.3538	26.47	158.93	185.40
42	28.29	13.59	.011284	2.769	88.62	.3611	26.81	158.61	185.42
43	28.90	14.20	.011296	2.712	88.52	.3687	27.16	158.28	185.44
44	29.52	14.82	.011308	2.656	88.43	.3765	27.51	157.95	185.46
45	30.15	15.45	0.011320	2.601	88.34	0.3844	27.86	157.62	185.48
46	30.79	16.09	.011332	2.548	88.24	.3925	28.21	157.29	185.50
47	31.44	16.74	.011344	2.497	88.15	.4005	28.56	156.96	185.52
48	32.10	17.40	.011356	2.446	88.05	.4088	28.92	156.62	185.54
49	32.77	18.07	.011368	2.397	87.96	.4172	29.27	156.28	185.55
50	33.45	18.75	0.011380	2.348	87.87	0.4259	29.61	155.95	185.56
51	34.15	19.45	.011392	2.302	87.78	.4345	29.96	155.61	185.57
52	34.86	20.16	.011404	2.256	87.67	.4433	30.31	155.27	185.58
53	35.58	20.88	.011416	2.211	87.60	.4523	30.66	154.93	185.59
54	36.31	21.61	.011428	2.167	87.51	.4615	31.00	154.59	185.59

* Inches of mercury below one standard atmosphere (29.92 in.) 14.696 lb. abs.
† For Internal Latent heat see Re. Eng. Vol. II No. 6; p. 235 (Dec. 1924).
‡ Standard ton temperatures.

TABLE XXXIII.—PROPERTIES OF SATURATED VAPOR OF SULPHUR DIOXIDE—SO_2—(*Continued*)

Tem.	Pressure		Volume		Density		Heat Content Above -40		
°F. t	Abs. lb./in.² p	Gage lb./in.² gp	Liquid ft.³/lb. v	Vapor ft.³/lb. V	Liquid lb./ft.³ $1/v$	Vapor lb./ft.³ $1/V$	Liquid Btu./lb. $h+$	Latent Btu./lb. $L=$	Vapor Btu./lb. H
55	37.05	22.35	0.011440	2.124	87.41	0.4708	31.36	154.24	185.60
56	37.80	23.10	.011452	2.083	87.31	.4801	31.72	153.89	185.61
57	38.56	23.86	.011464	2.043	87.22	.4894	32.08	153.54	185.62
58	39.33	24.63	.011476	2.003	87.13	.4992	32.42	153.19	185.61
59	40.12	25.42	.011488	1.964	87.04	.5092	32.76	152.84	185.60
60	40.93	26.23	0.011500	1.926	86.95	0.5194	33.10	152.49	185.59
61	41.75	27.05	.011512	1.889	86.86	.5294	33.44	152.14	185.58
62	42.58	27.88	.011524	1.853	86.77	.5396	33.79	151.78	185.57
63	43.42	28.72	.011536	1.816	86.68	.5507	34.14	151.42	185.56
64	44.27	29.57	.011548	1.783	86.59	.5609	34.49	151.06	185.55
65	45.13	30.43	0.011560	1.749	86.50	0.5717	34.84	150.70	185.54
66	46.00	31.30	.011572	1.716	86.41	.5827	35.19	150.34	185.53
67	46.88	32.18	.011585	1.683	86.32	.5943	35.54	149.98	185.52
68	47.78	33.08	.011598	1.652	86.22	.6054	35.88	149.62	185.50
69	48.69	33.99	.011611	1.621	86.12	.6170	36.23	149.25	185.48
70	49.62	34.92	0.011626	1.590	86.02	0.6290	36.58	148.88	185.46
71	50.57	35.87	.011639	1.557	85.92	.6423	36.93	148.51	185.44
72	51.54	36.84	.011652	1.532	85.82	.6527	37.28	148.14	185.42
73	52.51	37.81	.011666	1.503	85.72	.6657	37.63	147.77	185.40
74	53.48	38.78	.011680	1.476	85.62	.6777	37.97	147.40	185.37
75	54.47	39.77	0.011693	1.448	85.52	0.6907	38.32	147.02	185.34
76	55.48	40.78	.011706	1.422	85.42	.7030	38.67	146.64	185.31
77	56.51	41.81	.011719	1.396	85.33	.7163	39.01	146.26	185.27
78	57.56	42.86	.011732	1.371	85.23	.7295	39.36	145.88	185.24
79	58.62	43.92	.011746	1.343	85.13	.7446	39.71	145.50	185.21
80	59.68	44.98	0.011760	1.321	85.03	0.7570	40.05	145.12	185.17
81	60.77	46.07	.011773	1.297	84.93	.7720	40.39	144.74	185.13
82	61.88	47.18	.011786	1.274	84.84	.7850	40.73	144.36	185.09
83	63.01	48.31	.011800	1.253	84.74	.7980	41.08	143.97	185.05
84	64.14	49.44	.011814	1.229	84.64	.8140	41.43	143.58	185.01
85	65.28	50.58	0.011828	1.207	84.54	0.8285	41.78	143.19	184.97
86‡	**66.45**	**51.75**	**.011841**	**1.185**	**84.44**	**.8440**	**42.12**	**142.80**	**184.92**
87	67.64	52.94	.011854	1.164	84.35	.8590	42.46	142.41	184.87
88	68.84	54.14	.011868	1.144	84.25	.8740	42.80	142.02	184.82
89	70.04	55.34	.011882	1.124	84.15	.8998	43.15	141.62	184.77
90	71.25	56.55	0.011896	1.104	84.05	0.9058	43.50	141.22	184.72
91	72.46	57.76	.011909	1.084	83.96	.9225	43.85	140.82	184.67
92	73.70	59.00	.011923	1.065	83.86	.9390	44.19	140.42	184.61
93	74.98	60.18	.011937	1.047	83.77	.9551	44.53	140.02	184.55
94	76.30	61.60	.011951	1.028	83.67	.9730	44.86	139.62	184.49
95	77.60	62.90	0.011965	1.011	83.57	0.9890	45.20	139.23	184.43
96	79.03	64.33	.011979	.9931	83.47	1.007	45.54	138.83	184.37
97	80.40	65.70	.011993	.9759	83.37	1.025	45.88	138.43	184.31
98	81.77	67.07	.012008	.9591	83.27	1.043	46.22	138.03	184.25
99	83.14	68.34	.012002	.9425	83.17	1.061	46.56	137.62	184.18
100	84.52	69.82	0.012037	0.9262	83.07	1.080	46.90	137.20	184.10
105	91.85	77.15	.012110	.8498	82.57	1.176	48.88	135.14	183.72
110	99.76	85.06	.012190	.7804	82.03	1.281	50.26	133.05	183.31
115	108.02	93.32	.012275	.7174	81.46	1.394	51.93	130.92	182.85
120	120.93	106.23	.012360	.6598	80.90	1.515	53.58	128.78	182.36
125	126.43	111.73	0.012445	0.6079	80.35	1.645	55.31	126.51	181.82
130	136.48	121.78	.012530	.5595	79.81	1.787	56.85	124.39	181.24
135	147.21	132.51	.012620	.5158	79.23	1.947	58.47	122.15	180.62
140	158.61	143.91	.012720	.4758	78.61	2.102	60.04	119.90	179.94

‡ Standard ton temperatures.

TABLE XXXIV.—PROPERTIES OF SUPERHEATED VAPOR OF SULPHUR DIOXIDE—SO_2

David L. Fiske, Urbana, Ill.—1925. A. S. R. E. Data Book.

Temp. °F.	Abs. Pressure 4 lb./in.² Gage Pressure 21.7 in. vac. (Sat'n. Temp. − 32.60° F.)			Abs. Pressure 6 lb./in.² Gage Pressure 17.7 in. vac. (Sat'n. Temp − 19.37° F.)			Abs. Pressure 8 lb./in.² Gage Pressure 13.6 in. vac. (Sat'n. Temp. − 8.99° F.)			Abs. Pressure 10 lb./in.² Gage Pressure 9.6 in. vac. (Sat'n. Temp. − 1.34° F.)		
	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F.	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F.	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F.	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F.
t	*V*	*H*	*S*	*V*	*H*	*S*	*V*	*H*	*S*	*V*	*H*	*S*
(at sat'n)	(17.30)	(179.57)	(0.42043)	(12.22)	(181.14)	(0.41151)	(9.220)	(182.23)	(0.40482)	(7.520)	(182.95)	(0.40000)
−20	18.40	181.5	0.42487	......	......	......	......	......	......	......	......	......
−10	18.83	183.0	.42836	......	......	......	......	......	......	......	......	......
0	19.27	184.6	.43179	12.75	184.3	.41850	9.516	183.7	0.40871	7.545	183.2	0.40046
10	19.70	186.1	.43516	13.04	185.9	.42198	9.751	185.4	.41230	7.744	185.0	.40432
20	20.14	187.7	.43847	13.34	187.5	.42538	9.983	187.1	.41579	7.939	186.7	.40802
30	20.57	189.3	0.44161	13.63	189.1	0.42869	10.21	188.8	0.41922	8.030	188.4	0.41159
40	21.00	190.9	.44491	13.93	190.7	.43196	10.44	190.5	.42256	8.316	190.1	.41505
50	21.42	192.5	.44806	14.23	192.3	.43517	10.66	192.2	.42582	8.500	191.8	.41837
60	21.85	194.1	.45116	14.52	193.9	.43833	10.88	193.8	.42903	8.681	193.5	.42161
70	22.27	196.7	.45421	14.71	195.6	.44140	11.10	195.5	.43216	8.860	195.2	.42480
80	22.70	197.3	0.45722	15.11	197.2	0.44443	11.32	197.1	0.43524	9.038	196.9	0.42795
90	23.12	198.9	.46018	15.40	199.9	.44741	11.54	198.8	.43825	9.214	198.6	.43104
100	23.54	200.5	.46311	15.69	200.5	.45035	11.75	200.4	.44123	9.389	200.3	.43407
110	23.96	202.1	.46600	15.97	202.2	.45326	11.97	202.1	.44416	9.563	202.0	.43705
120	24.39	203.8	.46885	16.26	203.8	.45613	12.18	203.7	.44705	9.736	203.7	.43997
130	24.81	205.2	0.47167	16.54	205.3	0.45890	12.39	205.4	0.44990	9.908	205.4	0.44283
140	25.23	207.1	.47445	16.82	207.1	.46176	12.61	207.0	.45271	10.08	207.1	.44565
150	25.65	208.8	.47720	17.09	208.8	.46451	12.82	208.8	.45543	10.25	208.8	.44842
160	26.08	210.4	.47991	17.35	210.4	.46722	13.03	210.3	.45820	10.42	210.5	.45116
170	26.50	212.1	.48259	17.62	212.1	.46990	13.24	212.0	.46089	10.59	212.2	.45296
180	26.92	213.8	0.48523	17.88	213.7	0.47254	13.46	213.6	0.46353	10.76	213.8	0.45651
190	......	......	......	18.13	215.4	.47514	13.66	215.3	.46614	10.93	215.4	.45913
200	......	......	......	18.38	217.0	.47769	13.88	216.9	.46871	11.10	217.0	.46171

Temp. °F.	Abs. Pressure 15 lb./in.² Gage Pressure 0.30 lb./in.² (Sat'n. Temp. 14.43° F.)			Abs. Pressure 20 lb./in.² Gage Pressure 5.30 lb./in.² (Sat'n. Temp. 26.44° F.)			Abs. Pressure 25 lb./in.² Gage Pressure 10.30 lb./in.² (Sat'n. Temp. 36.33° F.)			Abs. Pressure 30 lb./in.² Gage Pressure 15.30 lb./in.² (Sat'n. Temp. 44.76° F.)		
(at sat'n)	(5.110)	(184.17)	(0.39091)	(3.878)	(184.86)	(0.38329)	(3.123)	(185.26)	(0.37754)	(2.614)	(185.48)	(0.37269)
20	5.192	185.4	0.39270	......	......	......	......	......	......	......	......	......
30	5.333	187.3	.39672	......	......	......	......	......	......	......	......	......
40	5.470	189.2	.40054	4.035	187.8	0.38959	3.181	186.1	0.37927	......	......	......
50	5.604	191.0	.40424	4.145	189.8	.39346	3.273	188.4	.38372	......	......	......
60	5.734	192.8	.40777	4.251	191.8	.39719	3.363	190.6	.38795	2.747	189.3	0.37969
70	5.862	195.6	0.41116	4.354	193.7	0.40080	3.451	192.7	0.39198	2.830	191.6	0.38428
80	5.988	196.4	.41443	4.454	195.6	.40429	3.536	194.7	.39582	2.907	193.8	.38848
90	6.112	198.2	.41765	4.552	197.5	.40758	3.618	196.7	.39945	2.980	195.9	.39236
100	6.233	199.9	.42076	4.648	199.3	.41093	3.696	198.6	.40291	3.052	197.9	.39603
110	6.353	201.6	.42383	4.742	201.1	.41415	3.772	200.5	.40625	3.122	199.9	.39955
120	6.471	203.3	0.42682	4.834	202.9	0.41726	3.848	202.4	0.40949	3.189	201.8	0.40293
130	6.588	205.6	.42976	4.925	204.7	.42027	3.923	204.2	.41261	3.254	203.7	.40619
140	6.705	206.7	.43264	5.015	206.5	.42322	3.998	206.0	.41568	3.318	205.6	.40935
150	6.821	208.4	.43548	5.104	208.2	.42613	4.073	207.8	.41866	3.381	207.5	.41241
160	6.937	210.1	.43825	5.193	209.9	.42898	4.145	209.6	.42156	3.443	209.3	.41539
170	7.052	211.8	0.44097	5.281	211.6	0.43176	4.216	211.4	0.42439	3.504	211.1	0.41829
180	7.167	213.5	.44366	5.369	213.3	.43449	4.287	213.2	.42717	3.565	212.9	.42112
190	7.282	215.2	.44630	5.456	215.0	.43716	4.358	215.0	.42988	3.625	214.7	.42387
200	7.396	216.9	.44889	5.542	216.7	.43977	4.428	216.7	.43253	3.685	216.5	.42657
210	......	......	......	5.629	218.4	.44234	4.498	218.4	.43413	3.744	218.3	.42921
220	......	......	......	5.715	220.1	0.44488	4.567	220.1	0.43769	3.803	220.1	0.43180
230	......	......	......	......	......	......	4.637	221.8	.44023	3.861	221.9	.43438
240	......	......	......	......	......	......	4.706	223.5	.44275	3.919	223.6	.43691
250	......	......	......	......	......	......	......	......	......	3.977	225.3	.43942
260	......	......	......	......	......	......	......	......	......	4.035	227.0	.44188

Note: **V** is Volume of Superheated Vapor, ft.³/lb.; **H** is Heat Content, Btu./lb., and **S** is Entropy, Btu./lb. °F.

TABLE XXXIV.—PROPERTIES OF SUPERHEATED VAPOR OF SULPHUR DIOXIDE—SO_2.—(*Continued*)

Temp. °F.	Abs. Pressure 40 lb./in.² Gage Pressure 25.30 lb./in.² (Sat'n. Temp. 58.83° F.)			Abs. Pressure 50 lb./in.² Gage Pressure 35.30 lb./in.² (Sat'n. Temp. 70.40° F.)			Abs. Pressure 60 lb./in.² Gage Pressure 45.30 lb./in.² (Sat'n. Temp. 80.29° F.)			Abs. Pressure 70 lb./in.² Gage Pressure 55.30 lb./in.² (Sat'n. Temp. 88.97° F.)		
	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F	Volume ft.³/lb.	Heat Content Btu./lb.	Entropy Btu./lb.°F.
t	*V*	*H*	*S*	*V*	*H*	*S*	*V*	*H*	*S*	*V*	*H*	*S*
(at sat'n)	(1.970)	(185.60)	(0.36470)	(1.577)	(185.45)	(0.35520)	(1.3144)	(185.16)	(0.35272)	(1.125)	(184.77)	(0.34789)
60	1.980	185.9	0.36544	...	.	.				.....	....	....
70	2.064	188.7	.37064	.	.		.		.	....	....	....
80	2.121	191.3	.37544	1.668	188.4	.36366	.	....	.	...	......	....
90	2.185	193.6	.37992	1.723	191.2	.36887	...	. .		....	....	....
100	2.246	196.1	.38415	1.775	193.9	.37369	1.288	191.4	0.36403	1.181	187.6	0.35443
110	2.304	198.3	0.38810	1.825	196.4	0.37815	1.346	194.3	0.36906	1.228	191.6	0.36020
120	2.360	200.4	.39183	1.872	198.8	.38234	1.403	197.0	.37375	1.272	194.8	.36545
130	2.413	202.5	.39541	1.917	201.1	.38627	1.459	199.5	.37810	1.313	197.6	.37028
140	2.465	204.6	.39881	1.961	203.3	.38998	1.514	201.9	.38217	1.352	220.3	.37478
150	2.515	206.5	.40209	2.003	205.4	.39353	1.563	204.2	.38603	1.389	202.9	.37897
160	2.565	208.5	0.40525	2.044	207.5	0.39691	1.608	206.5	0.38963	1.424	205.3	0.38291
170	2.614	210.4	.40831	2.084	209.6	.40015	1.650	208.6	.39310	1.457	207.6	.38662
180	2.662	212.3	.41127	2.123	211.6	.40327	1.689	210.7	.39639	1.489	209.9	.39014
190	2.709	214.2	.41416	2.161	213.4	.40628	1.726	212.8	.39956	1.521	212.0	.39348
200	2.755	216.0	.41694	2.199	215.4	.40919	1.751	214.8	.40260	1.551	214.1	.39670
210	2.800	217.9	0.41966	2.237	217.3	0.41200	1.785	216.8	0.40554	1.580	216.1	0.39978
220	2.845	219.7	.42233	2.274	219.2	.41477	1.819	218.7	.40839	1.608	218.1	.40275
230	2.889	221.5	.42494	2.311	221.1	.41748	1.853	220.7	.41118	1.636	220.1	.40564
240	2.933	223.3	.42751	2.347	223.0	.42015	1.885	222.6	.41391	1.664	222.1	.40845
250	2.977	225.1	.43007	2.383	224.9	.42275	1.917	224.5	.41657	1.691	224.1	.41120
260	3.021	227.0	0.43262	2.418	226.7	0.42535	1.948	226.4	0.41917	1.718	226.0	0.41389
270	.....	...		2.454	228.5	.42791	1.979	228.2	.42175	1.745	227.9	.41653
280	.....	.	.	2.489	230.3	.43045	2.010	230.1	.42431	1.771	229.8	.41912
290	......	...	...	.	. .	.	2.040	232.0	.42685	1.798	231.7	.42167
300	.....	...	.	.	.		2.070	233.8	0.42935	1.824	233.5	0.42418

Temp. °F.	Abs. Pressure 80 lb./in.² Gage Pressure 65.30 lb./in.² (Sat'n. Temp. 96.88° F.)			Abs. Pressure 100 lb./in.² Gage Pressure 85.30 lb./in.² (Sat'n. Temp. 110.15° F.)			Abs. Pressure 120 lb./in.² Gage Pressure 105.30 lb./in.² (Sat'n. Temp. 121.52° F.)			Abs. Pressure 140 lb./in.² Gage Pressure 125.30 lb./in.² (Sat'n. Temp. 131.64° F.)		
(at sat'n)	(0.9809)	(184.33)	(0.34357)	(0.7756)	(183.30)	(0.33605)	(0.6430)	(182.19)	(0.33154)	(0.5551)	(181.04)	(0.32388)
100	0.993	185.6	0.34571	..	...	.....	.. .	....		.	....	....
110	1.040	189.1	.35214	.	. .	.	.....			......	....	.....
120	1.084	192.5	.35797	0.8190	187.3	0.34296	....	....	..	....	....	.....
130	1.125	195.7	.36330	.8575	191.0	.34942	.		..	.....	....	.....
140	1.163	198.6	.36819	.8928	194.6	.35528	0.7085	190.1	0.34264	0.5734	185.1	0.33089
150	1.199	201.3	0.37270	0.9255	197.9	0.36061	0.7403	193.9	0.34904	0.6055	189.7	0.33777
160	1.232	203.9	.37692	.9561	200.9	.36558	.7700	197.4	.35484	.6345	193.6	.34442
170	1.263	206.4	.38093	.9848	203.7	.37009	.7972	200.6	.36012	.6613	196.3	.35041
180	1.292	208.7	.38461	1.012	206.4	.37431	.8228	203.7	.36494	.6861	200.8	.35588
190	1.320	211.0	.38813	1.038	209.0	.37829	.8470	206.7	.36936	.7092	204.0	.36088
200	1.347	213.3	0.39150	1.062	211.5	0.38203	0.8699	209.4	0.37348	0.7309	207.1	0.36548
210	1.374	215.5	.39471	1.086	213.8	.38556	.8916	212.0	.37737	.7513	210.0	.36976
220	1.400	217.5	.39780	1.109	216.1	.38892	.9124	214.5	.38104	.7707	212.7	.37379
230	1.426	219.6	.40079	1.131	218.4	.39214	.9324	217.0	.38451	.7892	215.4	.37758
240	1.451	221.6	.40369	1.152	220.5	.39524	.9515	219.3	.38785	.8070	217.9	.38118
250	1.476	223.6	0.40651	1.173	222.6	0.39824	0.9700	221.5	0.39106	0.8241	220.3	0.38461
260	1.500	225.6	.40926	1.194	224.7	.40114	.9880	223.7	.39416	.8405	222.6	.38789
270	1.524	227.6	.41195	1.213	226.8	.40397	1.006	225.9	.39713	.8564	224.9	.39105
280	1.547	229.5	.41459	1.232	228.8	.40673	1.023	228.0	.40002	.8720	227.1	.39408
290	1.570	231.5	.41719	1.251	230.8	.40944	1.040	230.1	.40284	.8970	229.3	.39701
300	1.593	233.4	0.41974	1.268	232.8	0.41207	1.056	233.2	0.40558	0.9017	231.5	0.39985
310	...	...	....	1.284	234.8	.41464	1.072	234.3	.40825	.9161	233.6	.40261
320	..	..	.....	1.299	236.7	.41716	1.088	236.3	.41085	.9302	235.7	.40529
330	.	.....	.....		.		1.104	238.3	.41338	.9441	237.7	.40791
340	....	......	...		..	.	1.120	240.3	0.41583	0.9579	239.7	0.41049

Note V is Volume of Superheated Vapor, ft.³/lb., H is Heat Content, Btu./lb., and S is Entropy, Btu./lb. °F

TABLE XXXV.—STANDARD TON DATA 86° and 5° F. VARIOUS REFRIGERANTS (Saturated Vapors.)

Compiled by Editor A. S. R. E. Data Book from various sources, including A. S. R. E. Circular No. 2. Properties of Refrigerants, and A. S. R. E. Circular No. 9. Tables of Thermodynamic Properties of Refrigerants. A. S. R. E. Data Book.

Refrigerant	R-11 Carbon Dioxide CO_2		R-28 Nitrous Oxide N_2O		R-21 Ethane C_2H_6		R-22 Propane C_3H_8		R-2 Ammonia NH_3		R-15 Methyl Chloride CH_3Cl		R-9 Sulphur Dioxide SO_2		R-18 Ethyl Chloride C_2H_5Cl.	
Subject	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°
Absolute pressure, lb./in.^{2}.....p...	1039.0	334.4	930.0	330.0	681.0	236.0	158.0	45.2	169.2	34.27	95.53	20.89	66.45	11.81	27.10	4.65
Gage pressure, lb./in.^{2}........g p....	1024.3	319.7	915.3	318.3	666.0	221.0	143.0	30.5	154.5	19.57	80.83	6.19	51.75	5.87*	12.40	−10.05
Atmospheres gage, At/in.^{2}....a g p..	69.7	21.75	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Volume-Liquid, ft.^{3}/lb........v.....	0.0267	0.0163	0.0256	0.0163	0.0569	0.0365	0.0329	0.0291	0.02691	0.02432	0.01793	0.01634	0.01184	0.1087	0.01822	0.01695
Volume-Vapor, ft.^{3}/lb.........V.....	0.0474	0.2673	0.0726	0.3080	0.122	0.629	0.681	2.34	1.772	8.150	1.075	4.530	1.185	6.421	3.29	17.06
Density-Liquid, lb./ft.^{3}.......1/v. .	37.41	61.22	39.06	61.27	17.80	27.40	30.37	34.33	37.16	41.11	55.8	61.0	84.44	92.00	54.88	59.00
Density-Vapor, lb./ft.^{3}........1/V...	21.09	3.741	13.80	5.25	8.20	1.59	1.47	4.27	0.5643	0.1227	0.930	0.2209	0.844	0.1558	0.3043	0.0586
Heat-Liquid, Btu./lb..........h.....	45.45	−13.16	...	...	...	...	51.0	3.0	138.9	48.35	59.34	21.19	42.12	14.11	23.1	−11.6
Heat-Latent, Btu./lb.........L.....	27.00	115.30	51.1	121.4	70.0	176.0	144.0	169.5	492.6	565.0	162.90	178.50	142.80	169.38	162.6	177.0
Heat-Vapor, Btu./lb..........H.....	72.46	102.14	...	...	...	...	195.0	172.0	631.5	613.35	222.25	199.76	184.92	183.49	185.7	165.4
Entropy-Liquid, Btu./lb. °F.........	0.0868	−0.0275	...	...	...	...	0.100	0.006	0.2875	0.1092	...	...	0.0878	0.0315	0.0445	0.0241
Entropy-Evaporation, Btu./lb. °F...	0.0495	0.2482	...	...	...	...	0.264	0.364	0.9029	1.2161	...	...	0.2617	0.3645	0.2978	0.3807
Entropy-Vapor, Btu./lb. °F.........	0.1363	0.2207	...	...	...	...	0.364	0.370	1.1904	1.3253	...	...	0.3495	0.3961	0.3423	0.3566
Compressibility-Liquid............	...	...	...	...	...	...	...	...	0.00115	0.00062	...	...	...	...	...	...
Specific heat-Liquid...............	...		...		...		...		...		...		...		...	
Specific heat-Vapor, cp............	0.2025		...		0.397		0.365		0.79	0.91	0.24		0.511		0.273	
Specific heat-Vapor, cv............	0.1558		...		0.324**		0.316**		0.4011 (−°)		0.20		...		...	
Ratio, cp/cv......................	1.3003 (32° F.)		...		1.224 (50° F.)		1.153 (−°)		...		1.1991(66.68°C.)		1.256(16-34°C.)		1.1257 (73° C.)	
Specific gravity																
Liquid (water 1).......	...		...		.5459(−126.9°F)		.5853 (−48.1°F.)		.6818(−28.03°F.)		.998 (−11.36°F.)		1.4601 (14° F.)		0.9232 (32° F.)	
Vapor (air 1)........	1.5290†		1.5297†		1.0493†		1.562†		0.5963†		1.784†		2.2638†		2.31 (—°)	
Critical pressure, lb./in.^{2} Abs..	1071.00		...	...	718.0		661.5		1651.0		969.2		1141.5		784.0	
Critical temperature, °F......	87.80		...	...	89.8		204.1		271.2		289.6		314.8		361.0	
Molecular weight............	44.000‡		44.016‡		30.046‡		49.062‡		17.031‡		50.481‡		64.065‡		64.497‡	
Melting point (1 at.) °F.....	−160.6‡		−152.3‡		−277.6‡		−309.8‡		−107.86‡		−143.68‡		−98.86‡		−217.66‡	
Boiling point (1 at.) °F...........	−108.4†		−128.2†		−126.9‡		−48.1‡		−28.0**		−10.66‡		14.00‡		53.96‡	

* Inches of mercury below one standard atmosphere (29.92 in.) 14.696 lbs. abs. ** Supplied by Editor.
† Bureau of Standards, Scientific Paper No. 529. Weight of a normal liter of air (at 0° C. and 760 mm. of mercury at 0° C), 1.2929 grams, taken as unity.
‡ International Critical Tables. †† Carbondioxide not liquid at atmospheric pressure.

TABLE XXXV.—STANDARD TON DATA 86° AND 5° F. VARIOUS REFRIGERANTS (Saturated Vapors). (*Continued*)

Refrigerant	R-24 Iso-Butane[1] C_4H_{10}		R-23 Butane C_4H_{10}		R-27 Ether[2] $(C_2H_5)_2O$		R-26 Carbon Bisulphide CS_2		R-29 Chloroform $CHCl_3$		R-25 Carbon Tetrachloride CCl_4		R-00 Dieline[3] $C_2H_2Cl_2$		R-00 Trieline[4] C_2HCl_3	
Subject	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°	86°	5°
Absolute pressure, lb./in.² . . . p	59.5	13.1	41.6	8.2	12.3	1.5	8.40	1.28	4.80		2.78		6.9	0.82	1.72	0.16
Gage pressure, lb./in.² . . . . . g p	44.8	3.3*	26.9	13.2*	4.62*	26.87*	12.82*	27.32*	20.15*		24.2*		−7.8	−13.88	−12.98	−14.54
Volume-Liquid, ft.³/lb. v	0.0294	0.0268	0.0283	0.0260										.0127		.0109
Volume-Vapor, ft.³/lb. V	1.52	6.41	2.24	9.98	5.4	35.0	9.15	48.07	10.50		14.8		8.5	63.0	25.2	240.0
Density-Liquid, lb./ft.³ 1/v	34.10	37.40	35.40	3.841										79.0		91.6
Density-Vapor, lb./ft.³ 1/V	0.658	0.156	0.446	0.100	0.188	0.0285	0.1058	0.0208	0.0952		0.07037		.118	.0159	.0397	.00416
Heat-Liquid, Btu./lb. . . . . h	50.5	2.5	48.5	2.5	29.5	−15.0	12.8	−7.2	12.63		10.80		23.2	1.35	20.1	1.17
Heat-Latent, Btu./lb. L	139.0	159.5	153.5	169.5	163.5	170.8	156.1	165.0	115.38		90.04		133.0	136.0	109.5	112.5
Heat-Vapor, Btu./lb. . . . . H	189.5	162.0	202.0	172.0	193.0	155.8	168.9	157.8	128.01		100.84		156.2	137.35	129.6	113.67
Entropy-Liquid, Btu./lb. °F	0.099	0.005	0.095	0.006									.0425	.0029	.0368	.00252
Entropy-Evaporation, Btu./lb. °F	0.255	0.333	0.281	0.364									.2435	.293	.201	.242
Entropy-Vapor, Btu./lb. °F	0.354	0.348	0.376	0.370									.286	.2959	.2378	.2445
Specific heat-Liquid													0.27		0.233	
Specific heat-Vapor, cp			0.351										.1625		.12	
Specific heat-Vapor, cv													.1425		.105	
Ratio, cp/cv	1.11 (−°)												1.14		1.14	
Specific gravity-Liquid (water 1)			0.6010‡		0.714‡		1.261				1.595		1.27		1.47	
Specific gravity-Vapor (air 1)			2.067						1.489				3.36		4.55	
Critical pressure, lb./in.² Abs.	537.1		303.4										[5]800 lb./in.²			
Critical temperature, °F	272.7		551.3										[5]470° F.			
Molecular weight	58.077‡		58.077‡		74.077‡		76.130		119.38		153.83		96.9		131.35	
Melting point (1 at.) °F	−229.0‡		−211.0‡		−177.34‡		−168.88‡		− 82.30‡		− 9.40		− 70		− 70	
Boiling point (1 at.) °F	+ 13.6‡		+ 33.08‡		+ 94.10‡		115.34‡		+142.16‡		+170.24		122		187	

* Inches of mercury below one standard atmosphere (29.92 in). 14.696 lbs. abs. ** Supplied by Editor.
† Bureau of Standards Scientific Paper No. 529. Weight of a normal liter of air (at 0° C. and 760 mm. of mercury at 0° C.), 1.2929 grams, taken as unity.
‡ International Critical Tables. 1—Isobutane (Trimethylmethane). 2—Ether (Ethyl or Sulphuric Ether).
3 Dieline (Stable isomers of Dichloroethylene). 4 Trieline (Trichloroethylene). 5 Approximate.

TABLE XXXVI.—SOLUBILITY OF AMMONIA IN WATER.*

Siebel—Compend of Mechanical Refrigeration. Nickerson & Collins Co., Chicago.

Temp.	Ammonia Content		Temp.		
°F.	$\frac{\text{Lb. }NH_3}{\text{Lb. }H_2O}$	$\frac{\text{Vol. }NH_3}{\text{Vol. }H_2O}$	°F.	$\frac{\text{Lb. }NH_3}{\text{Lb. }H_2O}$	$\frac{\text{Vol. }NH_3}{\text{Vol. }H_2O}$
32.0	0.899	1180	**122.0**	0.284	373
35.6	.853	1120	125.6	.274	359
39.2	.809	1062	129.2	.265	348
42.8	.765	1005	132.8	.256	336
46.4	.724	951	136.4	.247	324
50.0	0.684	898	**140.0**	0.238	312
53.6	.646	848	143.6	.229	301
57.2	.611	802	147.2	.220	289
60.8	.578	759	150.8	.211	277
64.4	.546	717	154.4	.202	265
68.0	0.518	683	**158.0**	0.194	254
71.6	.490	643	161.6	.186	244
75.2	.467	613	165.2	.178	234
78.8	.446	585	168.8	.170	223
82.4	.426	559	172.4	.162	212
86.0	0.408	536	**176.0**	0.154	202
89.2	.393	516	179.6	.146	192
93.2	.378	496	183.2	.138	181
96.8	.363	478	186.8	.130	170
100.4	.350	459	190.4	.122	160
104.0	0.338	444	**194.0**	0.114	149
107.6	.326	428	197.6	.106	139
111.2	.315	414	201.2	.098	128
114.8	.303	399	204.8	.090	118
118.4	.294	386	208.4	.082	107
......	......	......	(212.0	0.074	97)

Press. Abs.	32° F.		68° F.		104° F.		212° F.	
Lb./in.²	$\frac{\text{Lb. }NH_3}{\text{Lb. }H_2O}$	$\frac{\text{Vol. }NH_3}{\text{Vol. }H_2O}$	$\frac{\text{Lb. }NH_3}{\text{Lb. }H_2O}$	$\frac{\text{Vol. }NH_3}{\text{Vol. }H_2O}$	$\frac{\text{Lb. }NH_3}{\text{Lb. }H_2O}$	$\frac{\text{Vol. }NH_3}{\text{Vol. }H_2O}$	$\frac{\text{Gm. }NH_3}{\text{Lb. }H_2O}$	$\frac{\text{Vol. }NH_3}{\text{Lb. }H_2O}$
14.67	0.899	1.180	0.518	0.683	0.338	0.443	0.074	0.097
15.44	0.937	1.231	.535	.703	.349	.458	.078	.102
16.41	0.980	1.287	.556	.730	.363	.476	.083	.109
17.37	1.029	1.351	.574	.754	.378	.496	.088	.115
18.34	1.077	1.414	.594	.781	.391	.513	.092	.120
19.30	1.126	1.478	0.613	0.805	0.404	0.531	0.096	0.126
20.27	1.177	1.546	.632	.830	.414	.543	.101	.132
21.23	1.236	1.615	.651	.855	.425	.558	.106	.139
22.19	1.283	1.685	.669	.878	.434	.570	.110	.140
23.16	1.336	1.754	.685	.894	.445	.584	.115	.151
24.13	1.388	1.823	0.704	0.924	0.454	0.596	0.120	0.157
25.09	1.442	1.894	.722	.948	.463	.609	.125	.164
26.06	1.496	1.965	.741	.973	.472	.619	.130	.170
27.02	1.549	2.034	.761	.999	.479	.629	.135	.177
27.99	1.603	2.105	.780	1.023	.486	.638	......	......
28.95	1.656	2.175	0.801	1.052	0.493	0.647	......	......
30.88	1.758	2.309	.842	1.106	.511	.671	......	......
32.81	1.861	2.444	.881	1.157	.530	.696	......	......
37.74	1.966	2.582	.919	1.207	.547	.718	......	......
36.67	2.020	2.718	.955	1.254	.565	.742	......	......
38.60	......	......	0.992	1.302	0.579	0.764	......	......
40.53	......	......	......	......	.594	.780	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......

*For convenience the bodies of the above tables give the ammonia content of the saturated solutions at the various temperatures and pressures in both pounds of ammonia per pound of water and volumes of ammonia per volume of water.—Editor A. S. R. E. Data Book.

TABLE XXXVII.—HEAT OF ASSOCIATION OF AMMONIA.*

Mollier-Starr's Practical Refrigerating Engineers' Hand Book. Nickerson & Collins Co., Chicago.

NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3	NH_3 %	Btu./lb. NH_3
0	347	**5**	329	**10**	307	**15**	281	**20**	259	**25**	232	**30**	203	**35**	175	**40**	142	**45**	106	**50**	70	**55**	34
1	344	6	325	11	303	16	279	21	254	26	226	31	198	36	168	41	135	46	99	51	52	56	27
2	340	7	321	12	298	17	274	22	248	27	221	32	192	37	162	42	128	47	92	52	56	57	20
3	337	8	316	13	294	18	269	23	243	28	215	33	186	38	155	43	121	48	85	53	49	58	14
4	333	9	311	14	289	19	264	24	238	29	209	34	180	39	149	44	113	49	77	54	41	59	7
																						60 to 100-0	

*The above table, "Heat of Association of Ammonia," gives the heat of association and disassociation of one pound of ammonia entering or leaving ammonia solutions of various strengths The *total* heat liberated or taken up respectively when a pound of ammonia is absorbed or driven out of ammonia solutions of various strengths is the *heat of association* plus the *latent heat of vaporization*, corresponding to the observed temperature or pressure See tables of Properties of *Anhydrous* Ammonia.

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)

Temperatures ° F. corresponding to various percent concentrations (2 to 50%) and absolute pressures (10 to 200 pounds.)

Mollier, Experiments; Macintire, Computations, Starr's Practical Refrigerating Engineers' Hand Book, Nickerson & Collins Co.

Per cent, NH_3.	Absolute pressure.																
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2	169.0	173.0	178.5	181.8	185.6	189.5	193.2	197.0	201.5	203.5	206.5	209.5	212.3	215.0	217.5	220.1	222.4
4	161.0	165.4	169.5	173.3	177.0	180.9	184.7	188.4	191.5	194.6	197.5	200.9	203.0	205.6	207.9	210.5	212.8
6	153.0	157.0	161.0	165.0	168.5	172.5	176.0	179.1	182.4	185.7	188.8	191.4	194.0	196.5	199.0	201.4	203.7
8	143.5	148.3	152.7	156.4	160.5	164.0	167.9	170.8	174.0	177.9	180.1	182.7	185.3	188.0	190.3	192.5	195.0
10	137.4	141.0	144.5	148.4	151.8	155.0	158.8	162.0	165.0	168.0	171.1	173.9	176.5	179.1	181.4	183.7	186.0
12	129.0	132.5	136.7	140.6	144.3	147.8	151.3	154.6	157.6	160.4	163.1	165.6	168.0	170.6	172.9	175.0	177.2
14	120.5	124.6	129.0	133.0	136.7	140.0	143.6	147.0	150.0	152.7	155.5	158.0	160.6	162.9	165.1	167.4	169.7
16	113.0	117.0	121.4	125.4	129.5	132.6	136.0	139.0	142.0	144.6	147.4	149.8	152.1	154.6	156.9	159.0	161.3
18	107.5	110.0	113.5	118.0	121.5	125.0	128.1	131.3	134.4	137.0	139.7	142.3	144.7	147.0	149.2	151.4	153.5
20	99.0	103.0	106.8	110.5	114.0	117.6	120.6	129.0	126.7	129.5	132.0	134.5	137.0	139.3	141.6	143.7	145.7
22	92.0	95.5	99.2	103.0	106.5	110.0	113.3	116.2	119.1	122.0	124.6	127.0	129.5	131.6	133.9	136.0	138.0
24	86.0	89.7	93.5	97.0	100.0	103.1	106.0	109.0	111.8	114.5	117.0	119.6	122.4	124.8	127.0	129.4	131.5
26	79.2	82.6	86.0	90.0	93.0	96.0	99.5	102.4	105.3	108.0	110.6	113.2	115.6	118.1	120.1	122.1	124.1
28	73.4	77.0	81.0	84.4	87.8	90.7	83.5	96.0	98.8	101.3	103.6	106.2	108.7	111.0	113.3	115.5	117.3
30	66.5	70.6	74.5	77.5	80.0	83.8	86.7	89.6	92.1	94.7	97.0	99.3	101.8	104.0	106.3	108.5	110.5
32	61.0	64.5	68.0	71.0	74.0	77.0	79.8	82.3	85.0	87.5	90.0	92.3	94.5	96.9	99.0	101.0	103.0
34	55.0	59.0	62.4	65.6	68.8	71.6	74.3	76.8	79.4	81.7	84.0	86.5	88.5	90.6	92.8	94.8	96.8
36	49.0	52.7	56.5	60.0	63.0	66.0	69.0	71.7	73.8	76.1	78.5	80.5	82.6	84.7	86.8	88.9	90.8
38	43.0	47.0	50.5	54.0	57.0	60.0	63.0	65.5	68.0	70.2	72.5	74.5	76.6	78.7	80.7	82.7	84.6
40	37.0	41.0	44.5	48.0	51.0	53.5	56.2	59.5	61.0	63.5	66.0	68.2	70.4	72.6	74.8	76.9	79.0
42	31.6	35.7	39.4	42.9	46.0	48.6	51.4	53.9	56.3	58.7	61.0	63.2	65.2	67.3	69.1	71.0	73.9
44	27.5	30.2	34.0	37.0	40.5	43.5	45.9	48.5	50.8	53.0	55.3	57.4	59.8	61.6	63.5	65.4	67.1
46	21.2	24.9	28.5	31.7	34.9	37.6	40.4	43.0	45.4	47.6	49.7	51.7	53.8	56.0	57.8	59.8	61.5
48	16.0	19.8	23.0	26.0	29.0	32.0	34.9	37.4	40.0	42.2	44.4	46.5	48.5	50.5	52.4	54.2	56.0
50	11.0	14.6	18.0	21.0	24.0	26.9	29.7	32.0	34.4	36.6	38.9	40.9	42.8	44.7	46.6	48.5	50.3

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
2	224.6	226.9	229.0	231.1	233.1	235.1	237.0	238.9	240.7	242.4	244.2	246.0	247.6	249.4	251.0	252.5	254.2
4	215.3	217.7	219.9	221.9	224.0	226.0	228.0	229.8	231.6	233.4	235.3	237.0	238.7	240.3	242.0	243.4	245.0
6	205.0	208.1	210.6	212.4	214.5	216.4	218.3	220.1	222.0	223.5	225.0	226.5	228.0	229.5	231.0	232.0	233.5
8	497.3	199.5	201.7	203.7	205.6	207.5	209.3	211.3	213.0	214.9	216.6	218.1	219.9	221.4	223.0	224.5	226.0
10	188.4	190.5	192.7	194.6	196.6	198.7	200.5	202.3	204.1	205.9	207.3	209.0	210.6	212.3	213.8	215.2	216.8
12	179.4	181.5	183.4	185.5	187.4	189.4	191.2	193.0	195.0	196.7	198.4	200.0	201.7	203.3	204.9	206.3	207.9
14	171.8	173.6	175.8	177.6	179.5	181.4	183.2	185.0	186.8	188.5	190.2	192.0	193.6	195.2	196.9	198.2	199.7
16	163.4	165.4	167.4	169.4	171.3	173.2	175.1	177.0	178.9	180.6	182.3	183.7	185.4	187.1	188.6	190.0	191.4
18	155.5	157.4	159.9	161.2	163.0	165.0	166.8	168.4	170.0	171.8	173.4	175.1	176.7	178.3	179.9	181.1	182.7
20	147.8	149.8	151.8	153.8	155.7	157.6	159.3	161.0	162.5	164.3	165.9	167.3	168.7	170.2	171.5	172.8	174.2
22	140.0	142.0	144.0	146.0	147.9	149.7	151.5	153.2	155.0	156.5	158.0	159.6	161.0	162.7	164.0	165.5	167.0
24	133.5	135.4	137.3	139.2	141.0	142.8	144.4	146.0	147.6	149.2	150.8	152.2	153.7	155.2	156.6	158.0	159.4
26	126.1	128.1	130.0	131.9	133.7	135.5	137.2	138.9	140.4	142.0	143.6	145.2	146.6	148.2	149.5	151.0	152.2
28	119.4	121.3	123.0	125.0	126.6	128.3	129.8	131.5	133.1	134.6	136.0	137.5	139.0	140.6	142.0	143.4	144.8
30	112.5	114.4	116.0	117.8	119.6	121.2	122.8	124.5	126.0	127.4	129 0	130.5	132.0	133.5	134.7	136.0	137.4
32	105.0	107.0	109.0	111.0	113.0	114.9	116.7	118.0	119.8	121.3	122.8	124.3	125.5	127.1	128.3	129.8	131.0
34	98.8	100.8	102.7	104.5	106.3	108.0	109.6	111.3	112.8	114.5	115.8	117.3	118.5	120.0	121.3	122.5	123.8
36	92.7	94.4	96.2	98.1	100.0	101.7	103.2	104.9	106.5	108.0	109.5	111.0	112.3	113.5	115.0	116.2	117.5
38	86.4	88.2	90.0	91.8	93.5	95.1	96.6	98.2	99.5	101.0	102.5	104.0	105.4	106.8	108.0	109.2	110.5
40	80.2	82.2	84.1	86.0	87.7	89.2	90.8	92.4	93.7	95.3	96.7	98.0	99.4	101.0	102.0	103.5	104.7
42	74.5	76.1	77.8	79.4	81.0	82.5	84.0	85.5	86.9	88.2	89.7	91.2	92.6	94.0	95.0	96.5	98.0
44	68.8	70.4	72.0	73.6	75.1	76.7	78.2	79.6	81.1	82.4	83.7	85.0	86.5	87.8	89.0	90.4	91.7
46	63.3	65.0	66.5	68.1	69.6	71.2	72.7	74.0	75.4	76.7	78.2	79.6	80.9	82.0	83.0	84.5	85.7
48	58.0	59.8	61.3	62.7	64.3	65.8	67.3	68.7	70.3	71.5	72.8	74.2	75.5	76.7	78.0	79.0	80.4
50	52.0	53.5	55.1	56.8	58.3	59.9	61.3	62.5	64.1	65.5	66.9	68.3	69.7	70.9	72.2	73.4	74.7

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
2.......	255.6	257.1	258.6	260.0	261.5	262.9	264.3	265.8	267.1	268.4	269.8	271.2	272.4	273.8	274.9	276.0	277.9
4.......	246.4	247.9	249.5	250.8	252.2	253.6	255.0	256.4	257.9	259.2	260.4	261.7	262.9	264.0	265.3	266.6	267.7
6.......	235.0	236.5	238.0	239.6	241.0	242.5	244.0	246.4	248.0	249.3	250.6	251.8	253.0	254.4	255.5	256.7	258.0
8.......	227.4	228.7	230.3	231.7	233.1	234.5	236.0	237.3	238.6	239.8	241.0	242.3	243.5	244.7	245.8	247.0	248.2
10.......	218.3	219.8	221.2	222.8	224.3	225.7	227.0	228.3	229.7	230.8	232.3	233.6	234.8	236.0	237.3	238.4	239.6
12.......	209.3	210.7	211.9	213.3	214.6	215.9	217.2	218.4	219.8	221.0	222.4	223.5	224.6	225.7	226.8	228.0	229.2
14.......	201.1	202.5	204.0	205.3	206.5	207.8	209.1	210.2	211.7	212.4	214.0	215.2	216.3	217.4	218.5	219.7	220.8
16.......	192.9	194.1	195.5	196.8	198.0	199.4	200.5	201.8	203.0	204.1	205.3	206.5	207.7	208.8	209.8	210.9	212.0
18.......	184.0	185.5	186.8	188.1	189.4	190.7	192.0	193.1	194.4	195.5	196.7	197.8	198.9	200.0	201.0	202.0	203.1
20.......	175.5	177.0	178.5	179.9	181.0	182.2	183.6	184.8	186.0	187.2	188.4	189.7	190.8	192.0	193.2	194.2	195.4
22.......	168.3	169.5	170.9	172.1	173.4	174.6	175.9	177.0	178.2	179.5	180.6	181.7	182.8	183.9	184.9	185.9	187.0
24.......	160.8	162.0	163.5	164.9	166.1	167.3	168.7	170.0	171.2	172.4	173.6	174.8	175.8	177.0	178.0	179.0	180.0
26.......	153.5	155.0	156.2	157.5	158.6	159.9	161.0	162.5	163.5	164.5	165.6	166.7	167.8	169.0	170.0	171.0	172.1
28.......	146.0	147.4	148.9	150.1	151.5	152.7	154.0	155.2	156.5	157.6	158.8	160.0	161.0	162.0	163.0	164.1	165.2
30.......	138.8	140.1	141.3	142.6	143.8	145.1	146.1	147.3	148.4	149.7	150.8	151.8	152.9	153.9	154.9	155.9	157.0
32.......	132.1	133.5	134.7	135.8	137.0	138.1	139.4	140.4	141.4	142.5	143.5	144.6	145.6	146.6	147.6	148.7	149.7
34.......	125.0	126.2	127.5	128.6	129.9	131.0	132.0	133.0	134.1	135.2	136.3	137.3	138.3	139.5	140.5	141.4	142.4
36.......	118.7	120.0	121.1	122.4	123.5	124.7	125.8	126.9	127.9	129.0	130.0	131.0	132.0	133.0	134.0	135.0	136.0
38.......	111.9	113.2	114.5	115.7	117.0	118.1	119.4	120.5	121.7	122.8	123.9	125.0	126.0	127.0	128.0	129.0	130.0
40.......	105.9	107.0	108.1	109.5	110.6	111.8	112.9	114.0	115.2	116.3	117.3	118.3	119.4	120.5	121.5	122.4	123.4
42.......	99.2	100.5	101.7	193.0	104.0	105.1	106.3	107.4	108.5	109.6	110.6	111.6	112.5	115.5	114.5	115.5	116.4
44.......	93.0	94.3	95.5	96.7	97.9	99.0	100.1	101.2	102.3	103.4	104.4	105.5	106.5	107.4	108.3	109.3	110.3
46.......	86.9	88.1	89.4	90.5	91.7	92.8	94.0	95.0	96.1	97.2	98.3	99.4	100.3	101.3	102.3	103.3	104.2
48.......	81.5	82.6	83.8	84.9	86.0	87.1	88.3	89.4	90.4	91.5	92.5	93.5	94.5	95.5	96.5	97.5	98.5
50.......	75.9	77.0	78.1	79.3	80.4	81.4	82.6	83.7	84.8	85.9	86.9	87.9	88.8	89.8	90.8	91.7	92.6

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
2	278.6	279.7	280.8	282.0	283.2	284.3	285.4	286.5	287.7	288.8	290.0	291.0	292.0	293.0	294.0	295.0	296.0
4	268.9	270.2	271.2	272.3	273.5	274.6	175.7	276.9	277.9	278.9	280.0	281.0	282.0	283.0	284.0	285.0	285.9
6	259.1	260.3	261.4	262.5	263.6	264.8	265.9	267.0	268.0	269.0	270.0	271.0	272.0	273.0	274.0	274.9	275.9
8	249.4	250.6	251.6	252.7	253.8	255.0	256.0	257.1	258.1	259.0	260.0	261.0	262.0	263.0	264.0	264.9	265.8
10	240.9	242.0	243.0	244.1	245.2	246.3	247.4	248.4	249.5	250.5	251.3	252.3	253.2	254.1	255.0	255.9	256.8
12	230.2	231.5	232.5	233.5	234.5	235.7	236.8	237.9	238.9	240.0	240.9	241.8	242.7	243.7	244.6	245.5	246.5
14	221.8	222.9	223.9	225.0	226.0	227.0	228.0	229.0	230.1	231.2	232.0	233.0	234.0	234.9	235.8	236.8	237.7
16	213.0	214.0	215.1	216.1	217.2	218.2	219.3	220.3	221.3	222.3	223.1	224.1	225.1	226.0	227.0	227.9	228.8
18	204.2	205.2	206.3	207.3	208.4	209.5	210.5	211.5	212.5	213.5	214.3	215.3	216.3	217.2	218.1	219.0	220.0
20	196.4	197.4	198.4	199.4	200.3	201.3	202.2	203.1	204.1	205.0	205.7	206.7	207.6	208.3	209.2	210.2	211.1
22	188.0	189.0	190.0	191.1	192.1	193.1	194.0	195.0	196.0	196.9	197.8	198.7	199.7	200.5	201.4	202.3	203.1
24	181.2	182.2	183.1	184.1	185.1	186.0	187.0	188.0	189.0	190.0	190.7	191.6	192.5	193.4	194.2	195.1	196.0
26	173.1	174.2	175.2	176.2	177.2	178.2	179.2	180.1	181.0	182.0	183.0	184.0	184.9	185.7	186.5	187.3	188.2
28	166.3	167.3	168.2	169.1	170.0	171.0	172.0	172.9	173.8	174.7	175.4	176.3	177.3	178.0	178.8	179.7	180.4
30	158.0	159.0	159.9	160.9	161.9	162.8	163.7	164.6	165.5	166.4	167.2	168.1	169.0	169.9	170.8	171.7	172.4
32	150.7	151.5	152.5	153.4	154.2	155.2	156.1	157.0	157.9	158.8	159.7	160.5	161.4	162.3	163.1	164.0	164.9
34	143.4	144.4	145.3	146.2	147.2	148.1	149.0	150.0	151.0	151.9	152.7	153.6	154.5	155.3	156.0	157.0	157.8
36	137.0	137.9	138.9	139.8	140.8	141.7	142.6	143.5	144.4	145.3	146.0	146.9	147.8	148.6	149.5	150.2	151.0
38	131.0	131.9	132.8	133.7	134.6	135.5	136.4	137.3	138.1	138.7	139.6	140.5	141.3	142.0	142.8	143.6	144.3
40	124.3	125.2	126.1	127.0	128.0	128.9	129.8	130.5	131.4	132.3	133.0	133.9	134.5	135.4	136.2	137.0	137.8
42	117.4	118.3	119.1	120.0	120.9	121.7	122.5	123.3	124.1	124.9	125.6	126.4	127.2	128.0	128.8	129.5	130.3
44	111.2	112.0	112.9	113.8	114.7	115.5	116.3	117.1	118.0	118.8	119.5	120.3	121.0	121.9	122.6	123.3	124.0
46	105.1	106.0	106.8	107.7	108.5	109.4	110.3	111.0	111.8	112.6	113.3	114.1	115.0	115.6	116.5	117.2	117.9
48	99.4	100.2	101.1	101.9	102.8	103.6	104.4	105.3	106.0	106.7	107.5	108.2	109.0	109.8	110.4	111.2	111.8
50	93.5	94.4	95.3	96.1	97.0	97.8	98.5	99.3	100.0	100.8	101.6	102.5	103.2	104.0	104.7	105.4	106.3

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
2.......	297.0	298.0	299.0	299.9	300.8	301.7	302.6	303.5	304.4	305.3	306.1	306.8	307.8	308.7	309.5	310.4	311.1
4.......	286.8	287.7	288.6	289.5	290.4	291.3	292.1	293.0	293.9	294.7	295.6	296.5	297.3	298.1	299.0	299.8	300.7
6.......	276.8	277.7	278.5	279.5	280.4	281.3	282.2	283.0	283.9	284.8	285.6	286.5	287.4	288.1	289.0	289.8	290.5
8.......	266.7	267.8	268.5	269.9	270.3	271.2	272.0	272.9	273.8	274.6	275.5	276.4	277.3	278.0	278.9	279.7	280.5
10.......	257.8	258.7	259.5	260.3	261.2	262.0	262.9	263.8	264.6	265.3	266.2	267.0	267.9	268.6	269.5	270.3	271.1
12.......	247.5	248.4	249.4	250.3	251.2	252.0	252.9	253.8	254.7	255.6	256.5	257.3	258.1	258.9	259.7	260.5	261.2
14.......	238.6	239.5	240.5	241.4	242.2	243.0	243.9	244.8	245.7	246.4	247.2	248.1	248.9	249.6	250.4	251.1	251.9
16.......	229.7	230.6	231.6	232.3	233.2	234.0	235.0	235.9	236.7	237.4	238.2	239.0	239.9	240.7	241.4	242.2	242.9
18.......	220.9	221.8	222.6	223.5	224.3	225.1	226.0	226.8	227.7	228.5	229.3	230.1	230.9	231.6	232.4	233.2	233.9
20.......	212.0	212.9	213.8	214.6	215.3	216.1	216.9	217.8	218.6	219.3	220.1	221.0	221.8	222.6	223.3	224.0	224.7
22.......	204.0	204.8	205.6	206.4	207.1	208.0	208.8	209.6	210.4	211.1	211.9	212.7	213.5	214.3	215.0	215.7	216.4
24.......	196.9	197.7	198.4	199.2	200.0	200.8	201.5	202.2	203.0	203.7	204.5	205.2	206.0	206.6	207.3	208.1	208.9
26.......	189.0	189.9	190.7	191.5	192.3	193.0	193.7	194.5	195.3	196.0	196.8	197.5	198.2	198.9	199.7	200.4	201.0
28.......	181.2	182.0	182.8	183.6	184.3	185.1	185.9	186.7	187.3	188.0	188.8	189.5	190.3	190.9	191.6	192.3	193.0
30.......	173.1	174.0	174.9	175.8	176.6	177.2	178.1	178.9	179.8	180.4	181.2	182.0	182.7	183.4	184.0	184.8	185.4
32.......	165.8	166.5	167.3	168.1	169.0	169.8	170.6	171.3	172.0	172.7	173.5	174.2	175.0	175.8	176.5	177.2	177.9
34.......	158.6	159.4	160.2	161.0	161.7	162.5	163.3	164.0	164.7	165.5	166.3	167.0	167.8	168.5	169.3	169.9	170.7
36.......	151.8	152.5	153.3	154.0	154.7	155.5	156.3	157.0	157.7	158.5	159.2	160.0	160.7	161.4	162.0	163.5	163.5
38.......	145.1	145.9	146.7	147.3	148.1	148.9	149.6	150.4	151.1	151.8	152.4	153.1	153.8	154.6	155.2	155.8	256.4
40.......	138.5	139.2	140.0	140.7	141.4	142.2	142.7	143.5	144.2	144.9	145.6	146.2	147.0	147.7	148.3	149.0	149.7
42.......	131.0	131.8	132.5	133.3	134.0	134.7	135.5	136.1	136.9	137.5	138.3	139.0	139.8	140.4	141.0	141.8	142.5
44.......	124.8	125.5	126.3	127.0	127.8	128.4	129.2	129.9	130.6	131.3	131.9	132.6	133.4	134.0	134.7	135.2	136.0
46.......	118.7	119.3	120.1	120.7	121.5	122.2	122.9	123.5	124.2	125.0	125.7	126.3	126.9	127.6	128.3	128.9	129.6
48.......	112.5	113.2	114.0	114.6	115.3	116.0	116.7	117.3	118.0	118.7	119.3	120.0	120.6	121.3	121.9	122.6	123.2
50.......	106.9	107.5	108.3	109.0	109.8	110.3	111.0	111.7	112.2	113.0	113.7	114.3	114.9	115.5	116.2	116.9	117.3

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
2	312.0	312.8	313.7	314.5	315.4	316.2	316.8	317.7	318.5	319.3	320.0	320.8	321.5	322.3	323.0	323.7	324.5
4	301.5	302.3	303.1	304.0	304.7	305.6	306.3	307.1	308.1	308.7	309.5	310.3	311.0	311.9	312.6	313.4	314.1
6	291.3	292.1	292.8	293.6	294.4	295.3	295.9	296.6	297.4	298.1	298.9	299.6	200.4	301.2	301.9	302.6	303.4
8	281.3	282.0	282.8	283.5	284.4	285.1	285.8	286.7	287.4	288.2	289.0	289.7	290.4	291.2	291.9	292.5	293.4
10	271.9	272.8	273.5	274.3	275.0	275.8	276.4	277.1	278.1	278.7	279.4	280.1	280.9	281.4	282.3	282.9	283.5
12	262.0	262.7	263.4	264.1	264.9	265.6	266.4	267.0	267.8	268.5	269.2	269.9	270.5	271.3	272.0	272.7	273.4
14	252.6	253.4	254.0	254.7	255.5	256.1	256.0	256.6	257.3	259.0	259.8	260.4	261.1	261.8	262.5	263.0	263.9
16	243.7	244.7	245.0	245.7	246.5	247.3	248.0	248.7	249.3	250.0	250.7	251.4	252.0	252.7	253.4	254.0	254.7
18	234.6	235.3	236.0	236.6	237.2	238.0	238.5	239.4	240.0	240.7	241.5	242.0	242.7	243.5	244.0	244.7	245.3
20	225.5	226.3	227.0	227.8	228.5	229.1	229.9	230.5	231.2	231.9	232.6	233.2	233.9	234.5	235.2	235.9	236.5
22	217.1	217.9	218.5	219.2	220.0	220.6	221.1	222.0	222.7	223.2	224.0	224.5	225.3	225.9	226.5	227.1	227.8
24	209.7	210.4	211.0	211.7	212.4	213.0	213.7	214.3	215.0	215.6	216.1	216.8	217.4	218.0	218.7	219.2	220.0
26	201.8	202.4	203.1	203.8	204.5	205.1	205.6	206.4	207.1	207.8	208.4	209.0	209.7	210.3	211.0	211.5	212.0
28	193.6	194.4	195.0	195.7	196.4	197.1	197.6	198.4	199.0	199.6	200.3	200.9	201.4	202.0	202.5	203.1	203.8
30	186.1	186.9	187.4	188.0	188.7	189.4	189.9	190.6	191.3	191.9	193.6	193.2	193.9	194.4	195.0	195.6	196.1
32	178.6	179.3	180.0	180.6	181.3	182.0	182.5	183.1	183.9	184.5	185.1	185.8	186.3	186.0	187.6	188.2	188.8
34	171.3	172.0	172.6	173.3	174.0	174.6	175.0	175.9	176.5	177.2	177.8	178.4	179.0	179.5	180.4	180.9	181.5
36	164.1	164.8	165.5	166.0	166.7	167.3	168.0	168.6	169.3	169.8	170.5	171.0	171.7	172.3	172.9	173.5	174.0
38	157.0	157.7	158.4	159.0	159.7	160.3	160.9	161.4	162.1	162.7	163.3	164.0	164.5	165.2	165.8	166.4	167.0
40	150.3	150.8	151.5	152.1	152.8	153.4	154.0	154.6	155.2	155.8	156.4	157.0	157.6	158.1	158.8	159.4	160.0
42	143.1	143.8	144.5	145.2	145.8	146.4	147.0	147.8	148.3	149.0	149.7	150.3	150.9	151.5	152.0	152.7	153.3
44	136.6	137.2	137.9	138.5	139.2	139.9	140.5	141.1	141.8	142.4	143.0	143.7	144.3	144.8	145.4	146.0	146.6
46	130.3	130.8	131.5	132.1	132.9	133.4	134.0	134.7	135.2	133.9	136.5	137.0	137.7	138.3	138.9	139.5	140.0
48	123.8	124.5	125.1	125.7	126.3	127.0	127.5	128.1	128.7	129.3	130.0	130.6	131.1	131.6	132.3	132.9	133.9
50	118.0	118.6	119.2	119.9	120.4	121.0	121.5	122.1	122.8	123.4	123.8	124.3	125.0	125.5	126.3	126.9	127.5

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
2	325.2	325.9	326.5	327.3	328.0	328.6	329.4	330.0	330.7	331.3	332.0	332.7	333.4	334.0	334.7	335.4	336.0
4	314.9	315.6	316.3	317.0	317.7	318.4	310.0	319.6	320.3	321.0	321.7	322.3	323.0	323.6	324.2	324.8	325.5
6	304.1	304.8	305.5	306.2	306.9	307.5	308.2	308.9	309.6	310.2	310.9	311.5	312.2	312.8	313.5	314.0	314.7
8	294.2	294.9	295.5	296.2	296.9	297.5	298.2	298.9	299.6	300.3	300.9	301.5	302.1	302.7	303.4	304.0	304.6
10	284.3	284.9	285.5	286.2	286.9	287.5	288.2	288.8	289.4	290.3	290.8	291.4	291.9	292.7	293.2	293.8	294.4
12	274.1	274.7	275.4	276.0	276.8	277.4	278.0	278.7	279.3	280.0	280.6	281.3	281.8	282.5	283.1	283.7	284.3
14	264.5	265.1	265.9	266.5	267.1	267.8	268.4	269.1	269.7	270.4	271.0	271.7	272.3	272.9	273.5	274.1	274.7
16	255.3	256.0	256.6	257.3	257.9	258.5	259.1	259.8	260.4	261.0	261.6	262.3	262.9	263.5	264.0	264.7	265.3
18	246.0	246.7	247.3	248.0	248.5	249.1	249.8	250.5	251.0	251.7	252.2	252.8	253.4	254.0	254.6	255.3	255.8
20	237.1	237.8	238.3	239.0	239.6	240.3	240.9	241.5	242.0	242.7	243.3	243.7	244.4	245.0	245.0	246.8	256.8
22	228.4	229.0	229.7	230.3	230.9	231.6	232.2	232.8	233.4	234.0	234.5	235.1	235.0	236.3	237.0	237.5	238.1
24	220.7	221.2	221.7	222.4	223.0	223.7	224.2	224.8	225.5	226.0	226.6	227.1	227.8	228.4	228.9	229.4	230.0
26	212.6	213.4	214.0	214.6	215.2	215.8	216.3	217.0	217.6	218.1	218.7	219.3	219.9	220.4	221.0	221.8	222.3
28	204.5	205.0	205.6	206.3	206.9	207.4	208.1	208.7	209.3	209.9	210.5	211.0	211.6	212.2	212.8	213.4	213.9
30	196.9	197.4	198.0	198.5	199.2	199.8	200.3	200.9	201.3	202.0	202.5	203.0	203.6	204.1	204.7	205.3	205.8
32	189.4	190.0	190.6	191.1	191.8	192.4	192.9	193.4	194.0	194.5	195.1	195.6	196.1	196.6	197.2	197.8	198.3
34	182.0	182.6	183.2	183.8	184.3	184.9	185.8	186.0	186.6	187.2	187.6	188.2	188.7	189.3	189.8	190.4	190.9
36	174.6	175.2	175.8	176.4	177.0	177.6	178.2	178.7	179.3	179.8	180.3	180.9	181.4	182.0	182.5	183.0	183.5
38	167.7	168.2	168.8	169.3	170.0	170.5	171.0	171.6	172.2	172.7	173.2	173.8	174.2	174.8	175.3	175.8	176.3
40	160.6	161.1	161.8	162.3	162.9	163.4	164.0	164.5	165.0	165.6	166.1	166.7	167.2	167.8	168.3	168.9	169.4
42	153.9	154.4	155.0	155.6	156.1	156.7	157.3	157.8	158.3	158.8	159.5	160.0	160.4	161.0	161.5	162.0	162.5
44	147.1	147.7	148.2	148.8	149.4	150.0	150.5	151.0	151.5	152.0	152.6	153.1	153.6	154.2	154.7	155.2	155.7
46	140.6	141.1	141.7	142.2	142.8	143.3	143.9	144.5	145.0	145.5	146.0	146.5	147.0	147.6	148.0	148.5	149.0
48	134.0	134.5	135.0	135.6	136.2	136.7	137.2	137.8	138.4	138.9	139.4	140.0	141.5	141.0	141.6	142.1	142.6
50	128.1	128.5	129.1	129.8	130.2	130.9	131.3	131.8	132.4	132.9	133.3	133.9	134.2	134.7	135.2	135.7	136.2

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145
2	336.7	337.4	338.0	338.7	339.3	339.9	340.5	341.2	341.8	342.4	343.0	343.6	344.2	344.8	345.4	346.0	346.5
4	326.1	326.7	327.4	328.0	328.5	329.2	329.9	330.5	331.1	331.6	332.3	333.0	333.5	334.0	334.6	335.2	335.7
6	315.4	316.0	316.5	317.2	317.9	318.4	319.2	319.8	320.3	321.0	321.6	322.2	322.8	323.4	324.0	324.5	335.0
8	305.2	305.8	306.4	307.0	307.5	308.1	308.7	309.4	309.9	310.5	311.4	311.6	312.3	312.8	313.3	313.9	314.4
10	295.1	295.7	296.3	296.9	297.4	298.2	298.7	299.4	300.0	300.6	301.1	301.8	302.4	302.9	303.4	304.0	304.5
12	285.0	285.6	286.0	286.7	287.3	287.9	288.5	289.2	289.7	290.3	290.9	291.5	292.0	292.5	293.0	293.7	294.3
14	275.5	276.0	276.5	277.2	277.7	278.3	278.9	279.4	280.0	280.6	281.2	281.8	282.3	282.8	283.4	284.0	284.5
16	265.9	266.4	267.0	267.6	268.3	268.8	269.4	270.0	270.6	271.0	271.7	272.2	272.7	273.4	273.8	274.4	274.9
18	256.4	257.0	257.4	258.0	258.6	259.1	259.8	260.3	260.9	261.4	262.0	262.5	263.1	263.6	264.1	264.6	265.3
20	247.3	247.9	248.4	249.0	249.6	250.2	250.7	251.3	251.8	252.4	252.9	253.5	254.0	254.5	255.0	255.6	256.1
22	238.6	239.3	239.8	240.4	241.0	241.5	242.0	242.5	243.1	243.6	244.2	244.7	245.2	245.7	246.2	246.9	247.3
24	230.7	231.3	231.7	232.3	232.9	233.4	233.9	234.5	235.0	235.6	236.1	236.7	237.2	237.7	238.3	238.7	239.3
26	222.8	223.4	224.0	224.5	225.1	225.6	226.0	226.7	227.1	227.6	228.1	228.7	229.2	229.7	230.2	230.7	231.2
28	214.5	215.0	215.5	216.1	216.6	217.3	217.7	218.3	218.8	219.4	219.9	220.4	220.9	221.4	222.0	222.5	223.0
30	206.3	206.9	207.5	208.0	208.5	209.0	209.7	210.2	210.7	211.2	211.7	212.2	212.9	213.2	213.8	214.2	214.7
32	198.8	198.4	199.9	200.4	201.0	201.4	202.0	202.5	203.0	203.5	204.0	204.5	205.0	205.6	206.0	206.5	207.0
34	191.4	191.9	192.4	192.9	193.4	194.0	194.5	195.0	195.5	196.0	196.5	197.0	197.5	198.0	198.5	199.0	199.4
36	184.1	184.7	185.0	185.7	186.2	186.7	187.2	187.6	188.3	188.7	189.3	189.7	190.3	190.7	191.3	191.7	192.2
38	177.0	177.5	178.0	178.5	179.0	179.5	180.0	180.6	181.0	181.5	182.0	182.5	183.0	183.5	184.0	184.5	185.0
40	170.0	170.5	170.9	171.4	172.0	172.5	173.0	173.5	174.0	174.5	175.0	175.5	175.9	176.3	176.8	177.3	177.8
42	163.0	163.5	164.0	164.5	165.0	165.5	166.0	166.5	167.0	167.5	168.0	168.5	169.0	169.5	170.0	170.5	171.0
44	156.2	156.7	157.1	157.7	158.2	158.7	159.1	159.7	160.2	160.7	161.1	161.6	162.0	162.5	163.0	163.5	164.1
46	149.6	150.2	150.5	151.0	151.5	152.0	152.5	153.0	153.5	154.0	154.5	155.0	155.4	155.9	156.4	156.8	157.3
48	143.2	143.7	144.0	144.7	145.2	145.8	146.2	146.7	147.2	147.7	148.1	148.6	149.1	149.6	150.0	150.5	151.0
50	136.8	137.2	137.7	158.2	138.6	139.2	139.6	140.2	140.7	141.1	141.6	142.0	142.5	143.0	143.4	143.8	144.2

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162
2	347.1																
4	336.4	337.0	337.5														
6	335.7	336.3	336.9	337.4	337.9												
8	315.0	315.5	316.2	316.6	317.3	317.8	318.3										
10	305.0	305.6	306.3	306.8	307.4	307.8	308.4	309.0	309.4	310.0	310.5	311.0	311.6	312.1	312.6	313.0	313.6
12	294.7	295.3	295.8	296.4	297.0	297.5	298.0	298.5	299.0	299.6	300.2	300.7	301.2	301.7	302.2	302.5	303.2
14	285.0	285.6	286.1	286.7	287.3	287.7	288.3	288.8	289.3	289.9	290.4	290.9	291.4	292.0	292.4	292.9	293.3
16	275.5	276.0	276.5	277.0	277.5	278.1	278.6	279.1	279.6	280.3	280.7	281.3	281.7	282.2	282.8	283.1	283.7
18	265.7	266.4	266.9	267.4	268.0	268.5	269.0	269.5	270.0	270.5	271.0	271.4	272.0	273.5	273.0	273.3	273.8
20	256.7	257.3	257.6	258.1	258.6	259.2	259.7	260.3	260.7	261.2	261.7	262.1	262.6	263.2	263.6	264.1	264.5
22	247.9	248.4	248.9	249.4	250.0	250.4	250.9	251.5	251.9	252.4	252.9	253.3	253.9	254.3	254.9	255.3	255.8
24	239.9	240.3	240.8	241.3	241.9	242.3	242.8	243.3	243.7	244.3	244.8	245.3	245.7	246.3	246.7	247.2	247.6
26	231.6	232.3	232.8	233.3	233.7	234.2	234.7	235.1	235.6	236.2	236.6	237.0	237.4	237.9	238.4	238.7	239.3
28	223.5	224.0	224.5	225.0	225.5	226.0	226.5	227.0	227.4	227.9	228.4	228.9	229.3	229.8	230.3	230.7	231.2
30	215.3	215.8	216.3	216.7	217.3	217.7	218.3	218.7	219.2	219.8	220.2	220.7	221.1	221.6	222.0	222.6	223.0
32	207.5	208.0	208.5	209.0	209.4	209.8	210.3	210.7	211.1	211.6	212.1	212.6	213.1	213.5	213.8	214.3	214.6
34	199.9	200.3	200.8	201.3	201.7	202.1	202.6	203.0	203.5	204.0	204.4	204.9	205.3	205.7	206.1	206.5	206.9
36	192.6	193.1	193.6	194.0	194.5	195.1	195.5	196.0	196.4	196.9	197.4	197.8	198.3	198.8	199.1	199.5	199.9
38	185.4	185.9	186.3	186.8	187.3	187.7	188.1	188.6	189.1	189.5	190.0	190.4	190.8	191.2	191.7	192.1	192.6
40	178.2	178.6	179.1	179.6	180.1	180.5	181.0	181.5	182.0	182.4	182.9	183.3	183.8	184.2	184.6	185.0	185.5
42	171.5	172.0	172.4	172.9	173.3	173.8	174.2	174.6	175.1	175.5	175.9	176.3	176.9	177.3	177.7	178.0	178.4
44	164.5	165.0	165.4	165.9	166.3	166.7	167.2	167.5	168.0	168.5	168.7	169.3	169.8	170.3	170.8	171.0	171.4
46	157.7	158.1	158.6	159.0	159.4	159.8	150.3	160.8	161.3	161.7	162.1	162.5	162.9	163.4	163.8	164.2	164.5
48	151.5	152.0	152.4	152.9	153.3	153.7	154.1	154.7	155.0	155.3	155.8	156.3	156.7	157.1	157.5	157.9	158.3
50	144.7	145.1	145.5	146.0	146.4	146.8	147.3	147.7	148.0	148.5	149.0	149.4	149.8	150.3	150.7	151.0	151.5

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute pressure.																
	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179
2																	
4																	
6																	
8																	
10	314.1	314.7	315.1	315.6	316.1	316.6	317.1	317.6	318.1	318.7	319.2	319.7	320.3	320.8	321.2	321.7	322.2
12	203.7	304.1	304.6	305.1	305.6	306.1	306.6	307.1	307.6	308.1	308.6	309.1	309.6	310.1	310.6	311.0	311.6
14	293.8	294.2	294.8	295.2	295.8	296.2	296.8	297.1	297.6	298.1	298.5	299.0	299.5	300.0	300.5	301.0	301.5
16	284.1	284.6	285.0	285.5	286.0	286.4	286.9	287.3	287.8	288.3	288.7	289.2	289.6	290.1	290.6	291.1	291.5
18	274.3	274.8	275.2	275.7	276.1	276.7	277.2	277.6	278.0	278.5	279.0	279.5	280.0	280.5	281.0	281.4	281.9
20	265.0	265.5	266.0	266.5	267.0	267.5	267.9	268.4	268.9	269.3	269.9	270.3	270.8	271.3	271.8	272.3	272.8
22	256.2	256.6	257.0	257.5	258.0	258.4	258.9	259.3	259.7	260.2	260.6	261.1	261.6	262.1	262.5	263.0	263.4
24	248.0	248.5	249.0	249.4	249.9	250.3	250.6	251.0	251.5	252.0	252.5	253.0	253.4	253.8	254.3	254.6	255.1
26	239.7	240.3	240.7	241.1	241.5	242.0	242.5	243.0	243.4	243.8	244.2	244.6	245.0	245.5	246.0	246.3	246.8
28	231.6	232.0	232.5	232.9	233.3	233.7	234.0	234.5	234.9	235.4	235.8	236.3	236.7	237.1	237.5	238.0	238.5
30	223.5	224.0	224.4	224.9	225.3	225.8	226.3	226.7	227.1	227.5	228.0	228.4	228.8	229.3	229.7	230.1	230.6
32	215.0	215.4	215.9	216.3	216.6	217.0	217.3	217.7	218.2	218.6	219.0	219.5	220.0	220.4	220.8	221.2	221.7
34	207.4	207.7	208.1	208.4	208.8	209.2	209.7	210.0	210.4	210.9	211.3	211.7	212.0	212.5	213.0	213.4	213.8
36	200.3	200.6	201.0	201.4	201.9	202.2	202.5	202.9	203.3	203.7	204.0	204.4	204.8	205.2	205.6	206.0	206.4
38	193.0	193.4	193.8	194.1	194.6	194.9	195.2	195.6	195.9	196.3	196.7	197.0	197.4	197.8	198.2	198.6	199.0
40	186.0	186.4	186.9	187.2	187.7	188.0	188.5	188.9	189.3	189.8	190.2	190.5	190.9	191.2	191.6	192.0	192.4
42	178.9	179.2	179.6	180.0	180.3	180.6	181.0	181.4	181.9	182.2	182.5	183.0	183.3	183.7	184.1	184.5	184.9
44	171.8	172.2	173.5	173.9	173.3	173.6	174.0	174.3	174.7	175.0	175.3	175.8	176.2	176.8	177.0	177.3	177.8
46	165.0	165.3	165.7	166.0	166.4	166.8	167.2	167.5	167.8	168.3	168.6	169.0	169.3	169.7	170.2	170.5	170.9
48	158.7	159.0	159.4	159.8	160.2	160.5	160.7	161.2	161.5	161.9	162.2	162.7	163.0	163.3	163.7	164.1	164.5
50	152.0	152.3	152.7	153.1	153.6	154.1	154.5	154.9	155.2	155.5	156.0	156.3	156.7	157.2	157.6	158.1	158.3

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent. NH_3.	Absolute pressure.										
	180	181	182	183	184	185	186	187	188	189	190
2											
4											
6											
8											
10	322.7	323.1	323.6	324.0	324.5	325.0	325.5	326.0	326.5	326.0	327.0
12	312.0	312.5	313.0	313.4	313.9	314.3	314.7	315.2	315.7	316.1	316.5
14	302.0	302.4	302.9	303.3	303.7	304.2	304.6	305.1	305.6	306.0	306.5
16	292.0	292.5	293.0	293.5	293.9	294.4	294.9	295.3	295.7	296.2	296.6
18	282.4	282.9	283.3	283.7	284.2	284.7	285.1	285.6	286.0	286.5	287.0
20	273.3	273.6	274.1	274.6	275.0	275.5	276.0	276.5	277.0	277.5	278.0
22	263.9	264.3	264.7	265.2	265.6	266.1	266.5	267.0	267.5	268.0	268.5
24	255.5	256.0	256.5	257.0	257.4	257.8	258.2	258.7	259.1	259.6	260.0
26	247.2	247.6	248.0	248.4	248.9	249.3	249.7	250.2	250.6	251.0	251.5
28	238.9	239.3	239.8	240.2	240.6	241.0	241.5	241.9	242.4	242.8	243.2
30	231.1	231.4	231.8	232.2	232.6	233.1	233.5	234.0	234.4	234.8	235.1
32	222.0	222.5	223.0	223.4	223.8	224.2	224.7	225.1	225.5	226.0	226.4
34	214.2	214.5	215.0	215.4	215.9	216.3	216.7	217.0	217.5	218.0	218.3
36	206.8	207.2	207.5	207.9	208.3	208.7	209.0	209.3	209.8	210.2	210.6
38	199.3	199.7	200.0	200.3	200.7	201.1	201.6	201.9	202.3	202.6	203.0
40	192.8	193.2	193.6	193.9	194.3	194.7	195.0	195.3	195.7	196.1	196.5
42	185.3	185.7	186.0	186.4	186.9	187.3	187.6	188.0	188.3	188.8	189.2
44	178.2	178.5	178.9	179.3	179.7	180.1	180.5	180.9	181.3	181.7	182.0
46	171.3	171.7	172.0	172.4	172.8	173.3	173.6	174.0	174.3	174.7	175.2
48	164.9	165.3	165.8	166.0	166.4	166.7	167.1	167.5	167.9	168.3	168.6
50	158.7	159.1	159.5	159.9	160.3	160.7	161.0	161.4	161.8	162.0	162.4

TABLE XXXVIII.—PROPERTIES OF AQUA-AMMONIA (Percent Concentration Table)—(*Continued*)

Per cent, NH_3.	Absolute Pressure.									
	191	192	193	194	195	196	197	198	199	200
2										
4										
6										
8										
10	327.7	328.2	328.5	329.0	329.4	329.9	330.3	330.7	331.1	331.6
12	317.0	317.3	317.9	318.3	318.7	319.1	319.6	320.0	320.0	320.7
14	307.0	307.4	307.9	308.4	308.8	309.3	309.8	310.3	310.7	311.1
16	297.1	297.6	298.0	298.5	299.0	299.5	300.0	300.5	300.9	301.3
18	287.4	287.9	288.4	288.9	289.3	289.9	290.3	290.8	290.3	291.7
20	278.3	278.9	279.3	279.9	280.3	280.8	281.3	281.7	282.1	282.7
22	268.9	269.3	269.8	270.3	270.7	271.2	271.6	272.1	272.5	273.0
24	260.5	260.9	261.4	261.8	262.3	262.7	263.0	263.6	264.0	264.5
26	251.9	252.3	252.8	253.0	253.5	253.9	254.4	254.8	255.3	255.8
28	243.7	244.0	244.5	244.9	245.4	245.8	248.3	246.7	247.2	247.5
30	235.6	236.0	236.4	236.8	237.2	237.7	238.2	238.7	239.0	239.3
32	226.9	227.3	227.7	228.2	228.7	229.1	229.5	230.0	230.4	230.8
34	218.7	219.2	219.6	220.0	221.4	220.8	221.2	221.7	222.0	222.5
36	211.0	211.3	211.6	212.0	212.4	212.9	213.2	213.7	214.0	214.4
38	203.3	203.8	204.2	204.5	204.9	205.2	205.6	206.0	206.4	206.8
40	197.0	197.3	197.7	198.1	198.4	198.7	199.2	199.4	199.9	200.1
42	189.5	190.0	190.3	190.7	191.1	191.5	191.9	192.3	192.7	193.0
44	182.4	182.8	183.2	183.5	183.9	194.3	184.7	185.1	185.5	185.9
46	175.5	175.9	176.3	176.7	177.1	177.4	177.9	178.3	178.7	179.0
48	169.0	169.3	169.7	170.1	170.5	170.9	171.2	171.7	172.0	172.5
50	162.8	163.2	163.5	163.9	164.2	164.7	165.0	165.3	165.6	166.0

TABLE XXXIX.—PROPERTIES OF AQUA-AMMONIA ABOVE 50%. (Percent Concentration Table)

Temperatures ° F. corresponding to various percent concentrations (50 to 100%) and absolute pressures (1 to 155 pounds).
Accuracy: To first decimal place of degrees. Boiling temperatures shown make continuously smooth curves with those of the preceding table.

Von Strombeck, Mollier, Experiments; Starr, Computations. Starr's Practical Engineers' Hand Book.

PER CENT AMMONIA	Pounds Absolute Pressure												
	1	2	3	4	5	6	7	8	9	10	15	20	25
52%	− 57.0	−40.0	−28.0	−19.5	−12.0	− 6.0	+ 1.0	+ 3.5	+ 7.0	+10.0	25.5	39.0	49.0
54%	− 60.5	−44.0	−31.5	−22.5	−16.0	− 9.0	− 4.0	+ 0.5	+ 4.0	+ 7.0	24.5	35.0	45.5
56%	− 63.0	−47.5	−34.5	−25.5	−19.0	−12.5	− 7.0	− 2.5	+ 1.0	+ 4.0	20.5	32.0	42.0
58%	− 65.0	−50.0	−37.0	−28.0	−21.0	−16.0	−10.0	− 5.5	− 2.0	+ 1.0	17.0	29.0	39.0
60%	− 67.0	−52.0	−39.5	−30.5	−23.5	−17.5	−12.5	− 8.5	− 5.0	− 1.5	15.0	26.0	36.0
62%	− 70.0	−55.0	−42.5	−33.5	−26.0	−20.0	−15.0	−11.0	− 7.5	− 4.0	11.5	23.0	33.0
64%	− 72.0	−57.5	−44.5	−36.0	−28.5	−22.5	−18.0	−13.5	−10.0	− 7.0	8.5	20.0	30.0
66%	− 74.0	−60.0	−47.0	−38.5	−31.0	−25.0	−20.0	−16.0	−12.0	− 9.0	7.9	17.5	27.0
68%	− 77.0	−62.5	−50.0	−40.0	−33.0	−27.0	−22.0	−17.5	−14.5	−11.5	+ 4.5	15.0	24.5
70%	− 79.0	−65.0	−51.5	−42.5	−35.0	−29.0	−24.0	−20.5	−17.0	−14.0	+ 2.5	12.5	22.0
72%	− 81.0	−67.0	−53.5	−45.0	−37.0	−31.5	−27.0	−23.0	−19.5	−16.5	− 1.0	10.0	19.0
74%	− 82.5	−69.0	−55.5	−47.0	−39.5	−33.5	−29.0	−25.0	−21.5	−18.5	− 2.5	7.5	17.5
76%	− 84.5	−70.5	−57.5	−49.0	−42.0	−36.0	−31.5	−27.0	−23.5	−20.5	− 5.0	5.5	15.0
78%	− 86.0	−72.5	−59.5	−51.0	−43.5	−38.0	−33.0	−29.0	−25.0	−22.5	− 7.5	+ 3.5	13.0
80%	− 87.5	−74.5	−61.5	−53.0	−45.5	−39.5	−35.0	−31.0	−27.0	−24.5	−10.0	+ 1.0	10.5
82%	− 91.0	−77.0	−63.0	−54.5	−47.0	−41.0	−37.0	−33.0	−30.0	−26.5	−11.5	− 1.0	8.5
84%	− 92.5	−79.5	−65.0	−55.0	−49.0	−42.5	−38.5	−35.0	−32.0	−28.5	−13.0	− 3.0	6.5
86%	− 94.0	−80.5	−67.0	−57.5	−50.5	−44.5	−40.0	−37.5	−34.0	−30.5	−15.0	− 5.0	+ 4.5
88%	− 95.0	−81.5	−69.0	−59.5	−53.0	−47.0	−42.5	−39.0	−35.5	−32.5	−17.0	− 6.5	+ 2.5
90%	− 96.0	−83.0	−71.0	−62.0	−55.0	−49.0	−44.0	−40.5	−37.0	−34.5	−19.0	− 8.0	− 0.5
92%	− 98.0	−84.0	−72.0	−63.5	−56.0	−50.5	−45.5	−42.0	−38.5	−35.5	−20.5	−10.5	− 1.0
94%	− 99.0	−85.0	−74.5	−65.0	−58.0	−52.5	−47.5	−43.5	−40.0	−37.0	−22.0	−12.0	− 3.0
96%	−100.0	−85.5	−75.5	−66.0	−59.5	−54.5	−49.0	−45.0	−42.0	−38.5	−23.5	−13.5	− 4.5
98%	−101.5	−86.0	−77.0	−67.0	−61.0	−55.5	−50.5	−46.0	−43.5	−40.0	−25.5	−14.5	− 6.5
100%	−105.0	−90.0	−80.0	−68.5	−62.5	−57.0	−52.0	−48.5	−45.0	−42.0	−27.5	−16.5	− 8.0

TABLE XXXIX.—PROPERTIES OF AQUA-AMMONIA, ABOVE 50%, (Percent Concentration Table)—(*Continued*).

Per Cent Ammonia	Pounds Absolute Pressure												
	30	35	40	45	50	55	60	65	70	75	80	85	90
52%	55.5	64.5	70.0	77.0	81.5	87.0	91.6	96.0	100.5	104.5	108.0	111.5	114.5
54%	54.5	61.0	67.0	73.0	78.5	83.5	87.5	92.0	96.5	100.0	104.0	108.0	110.5
56%	50.5	57.5	64.0	70.0	75.0	80.0	84.0	88.5	92.5	97.0	100.0	103.5	106.5
58%	47.0	54.0	60.5	66.5	71.5	76.5	81.0	85.0	89.0	93.0	97.0	100.5	103.0
60%	43.5	51.0	57.5	63.0	66.5	73.0	78.0	82.0	86.0	90.0	93.5	97.0	100.0
62%	41.5	48.0	54.5	60.0	65.0	70.0	75.0	79.0	83.0	87.0	90.5	94.0	97.0
64%	38.0	45.0	51.5	57.0	62.5	67.0	71.5	75.5	80.0	83.0	87.0	91.0	94.0
66%	35.0	42.5	48.0	54.0	59.5	64.0	68.5	72.5	76.5	81.5	84.5	87.5	90.5
68%	33.0	39.5	42.0	51.5	56.5	61.0	65.5	70.0	74.0	77.5	81.0	84.5	87.5
70%	30.0	37.0	43.0	48.0	53.5	58.5	63.0	67.0	71.0	75.0	78.0	81.5	84.5
72%	27.0	34.5	40.5	45.5	51.0	56.0	60.0	64.0	68.5	72.5	75.5	79.0	82.0
74%	25.0	32.0	38.0	43.5	48.5	53.0	57.5	61.5	66.0	69.5	73.0	76.5	79.5
76%	22.5	30.0	36.0	41.5	46.5	51.0	55.5	59.5	63.0	67.0	70.5	74.0	77.0
78%	20.5	27.5	33.0	39.0	44.0	47.5	53.0	57.0	61.0	64.5	68.0	71.5	74.0
80%	18.0	25.0	31.0	36.5	41.5	46.0	51.0	55.0	58.5	62.0	65.5	69.0	71.5
82%	16.0	23.0	29.0	34.5	40.0	44.0	48.5	52.5	56.0	59.5	63.0	66.5	69.5
84%	14.0	21.0	27.0	32.5	37.5	41.5	46.0	50.0	53.5	57.5	61.0	64.0	67.0
86%	12.5	19.0	25.0	30.0	35.0	39.0	44.0	47.5	51.5	55.0	58.0	62.0	65.0
88%	10.0	17.0	23.0	28.5	33.5	37.5	42.0	46.0	49.5	53.5	56.5	60.0	62.5
90%	8.0	15.0	21.0	26.0	31.0	35.0	40.0	43.5	47.5	51.0	54.5	58.0	60.5
92%	6.5	13.0	19.0	24.0	29.0	33.5	37.5	42.0	45.5	49.0	52.0	55.0	58.0
94%	4.5	11.0	17.5	22.5	27.5	31.5	35.1	40.0	43.5	46.5	50.0	53.5	56.5
96%	2.5	9.5	15.5	20.5	25.0	29.5	33.5	38.0	41.5	45.0	48.5	51.5	54.5
98%	+1.0	7.5	13.5	18.5	23.0	27.5	31.5	36.0	40.0	43.0	46.5	50.0	52.5
100%	−0.5	6.0	11.0	17.0	21.5	26.0	30.5	34.5	38.0	41.0	44.5	47.5	50.5

TABLE XXXIX.—PROPERTIES OF AQUA-AMMONIA, ABOVE 50%, (Percent Concentration Table)—(*Continued*).

Per Cent Ammonia	Pounds Absolute Pressure												
	95	100	105	110	115	120	125	130	135	140	145	150	155
52%	118.0	120.5	124.0	126.0	129.5	132.0	134.5	137.0	139.0	141.5	144.0	146.0	148.0
54%	113.0	116.5	120.0	122.5	125.5	128.0	130.5	132.5	135.0	137.5	139.5	142.0	144.0
56%	109.5	113.0	116.0	119.0	121.5	124.0	126.5	128.5	130.5	133.0	135.5	138.0	140.0
58%	106.0	109.5	113.0	115.5	118.5	120.5	123.0	125.0	127.0	129.5	132.0	134.5	136.0
60%	103.0	106.0	109.0	111.5	114.5	116.5	119.0	121.5	123.5	126.0	128.5	130.5	132.0
62%	100.0	103.0	106.0	108.5	111.0	113.5	115.5	118.0	130.5	123.0	125.0	127.0	129.0
64%	96.5	99.5	103.0	105.0	107.5	110.0	112.5	115.0	117.0	119.5	121.5	124.0	125.5
66%	93.5	96.5	99.5	102.0	104.5	107.0	109.5	111.5	113.5	115.5	118.0	120.5	122.0
68%	90.5	93.5	96.5	98.0	101.5	104.0	106.5	108.5	111.0	113.0	114.5	117.0	119.0
70%	87.5	90.5	93.5	96.0	98.5	101.0	103.0	105.5	108.0	110.0	112.0	114.5	116.0
72%	85.0	87.5	91.0	93.0	95.5	98.0	100.5	103.0	105.0	107.0	109.0	111.5	113.0
74%	82.5	85.0	88.0	90.5	93.0	95.5	97.5	100.0	102.5	104.5	106.5	108.5	110.0
76%	79.5	82.0	85.5	87.5	90.5	92.5	95.0	97.5	99.5	101.5	103.5	106.0	107.5
78%	77.0	79.5	83.0	85.0	87.5	90.0	92.0	94.0	97.0	99.0	101.5	103.5	105.0
80%	74.5	77.0	80.5	82.5	85.0	87.5	89.5	92.5	94.5	96.5	98.5	100.5	102.0
82%	72.0	75.0	78.0	80.5	83.0	85.0	87.0	89.5	92.0	94.0	96.0	98.0	99.5
84%	70.0	72.5	75.5	78.0	80.5	83.0	85.0	87.0	89.5	91.5	93.5	95.5	97.5
86%	67.5	70.0	73.5	75.5	78.0	80.5	82.5	85.0	87.0	89.5	91.0	93.0	95.0
88%	65.0	68.0	71.0	73.5	76.0	78.0	80.5	82.5	85.0	87.0	89.0	91.0	92.5
90%	63.0	66.0	69.0	71.0	74.0	76.0	78.5	80.5	82.5	85.0	86.5	88.5	90.5
92%	60.5	64.0	66.5	69.0	71.5	74.0	76.5	78.5	80.5	82.5	84.5	86.5	88.0
94%	59.0	62.0	64.5	66.5	69.5	71.5	74.0	76.5	78.5	80.5	82.5	84.5	86.0
96%	57.5	60.0	63.0	65.0	67.5	70.0	72.5	74.5	76.5	78.5	80.5	82.5	84.0
98%	55.5	58.0	60.5	63.0	65.5	67.5	70.0	72.5	74.5	76.5	78.5	80.5	82.0
100%	53.5	56.0	58.5	61.0	63.5	66.0	68.0	70.5	72.5	74.5	76.5	78.5	80.0

TABLE XXXIX.—PROPERTIES OF AQUA-AMMONIA, ABOVE 50%, (Percent Concentration Table)—(*Continued*).

Per Cent Ammonia	Pounds Absolute Pressure											
	160	165	170	175	180	185	190	195	200	205	210	215
52%	150.0	152.5	154.0	157.0	158.5	160.0	161.5	163.5	165.0	167.0	168.5	170.5
54%	146.0	148.0	150.0	152.0	154.0	156.0	157.0	159.5	161.0	162.5	164.5	166.0
56%	142.0	144.0	146.0	148.0	150.0	151.5	153.5	155.0	157.0	158.5	160.0	162.0
58%	138.0	140.5	142.5	144.0	146.0	148.0	149.5	152.5	153.0	154.5	156.0	158.0
60%	134.0	136.5	138.5	140.5	142.5	144.0	146.0	147.5	149.0	151.0	153.0	154.0
62%	131.0	133.0	135.0	137.0	139.0	140.5	142.5	144.0	145.5	147.0	149.0	150.5
64%	127.5	130.0	131.5	133.5	135.5	137.5	139.0	140.5	142.0	144.0	145.5	147.0
66%	124.5	126.5	128.5	130.5	132.0	134.0	135.5	137.0	139.0	140.5	142.0	144.5
68%	121.0	123.0	125.0	127.0	129.0	130.5	132.5	134.0	135.5	137.0	139.0	140.5
70%	118.0	120.0	122.0	124.0	126.0	127.5	129.5	131.0	132.5	134.5	136.5	137.5
72%	115.0	117.0	119.0	121.0	123.0	124.5	126.5	128.0	129.5	131.0	132.5	134.0
74%	112.5	114.5	116.5	118.0	120.0	121.5	123.0	125.0	126.5	128.0	130.0	131.5
76%	110.0	112.0	113.5	115.5	117.5	119.0	120.5	122.0	124.0	125.5	127.0	128.5
78%	107.0	109.0	111.0	112.5	114.5	116.0	118.0	119.5	121.0	122.5	124.0	126.0
80%	104.5	106.5	108.5	110.0	112.0	114.0	115.5	117.0	118.5	120.0	121.5	123.0
82%	102.0	104.0	106.0	107.5	109.0	111.0	112.5	114.0	116.0	117.5	119.0	120.5
84%	99.5	101.5	103.0	105.0	107.0	108.5	110.5	112.0	113.5	115.0	116.5	118.0
86%	97.0	99.0	101.0	102.5	104.5	106.0	107.5	109.5	110.5	112.5	114.0	115.5
88%	95.0	96.5	98.5	100.5	102.0	103.5	105.5	107.0	108.5	110.0	111.5	113.0
90%	92.5	94.5	96.0	98.0	99.5	101.0	103.0	104.5	106.0	107.5	109.0	111.0
92%	90.5	92.0	94.0	95.5	97.5	99.0	101.5	102.5	104.0	105.5	107.0	108.5
94%	87.5	90.0	91.5	93.5	95.5	96.5	98.5	100.0	101.5	103.0	105.0	106.5
96%	86.0	88.0	90.0	91.5	93.0	95.0	96.5	98.0	99.5	101.0	102.5	104.0
98%	84.0	86.0	88.0	89.5	92.0	93.0	94.5	96.0	97.5	99.0	100.5	102.0
100%	82.5	85.5	87.5	89.0	91.0	92.5	94.0	95.5	97.0	97.0	98.5	100.0

TABLE XL.—SOLUBILITY OF GASES IN WATER AT ATMOSPHERIC PRESSURE

1 Vol. Water dissolves Vols. Gas.	32° F.	39.2° F.	50° F.	60° F.	70° F.
Air	0.0247	0.0224	0.0195	0.0179	0.0171
Ammonia	1049.6	941.9	812.8	727.2	654.0
Carbon Dioxide	1.7987	1.5126	1.1847	1.0020	0.9014
Sulphur Dioxide	79.789	69.828	56.647	47.276	39.374
Marsh Gas	0.0545	0.0499	0.0437	0.0391	0.0350
Nitrogen	0.0204	0.0184	0.0161	0.0148	0.0140
Hydrogen	0.0193	0.0193	0.0191	0.0193	0.0193
Oxygen	0.049	0.0372	0.0325	0.0279	0.0284

TABLE XLI.—COMPRESSIBILITY OF LIQUIDS.*

Temperature Degrees F.	Ammonia	Sulphur Dioxide	Carbon Dioxide
32	0.000111	0.000118	0.000824
59	0.000130	0.000134	0.002259
77	0.000148	0.000149	0.008400

*Kälte Industrie, March, 1915.

CHAPTER V

HEAT TRANSFER

Heat Transmission.—Heat is transmitted through a substance when there is a temperature difference, and is caused by the natural tendency of heat toward a temperature equilibrium. The heat flow is always from a region of higher temperature to a region of lower temperature, and may occur in three ways: Conduction, radiation and convection.

The rate of heat transfer from one region to another, depends on the amount of surface, the difference in temperature and the material through which the flow occurs. The rate of transfer through various materials has been determined experimentally by many scientists, the most reliable of which are given in Table XLII as compiled by the Bureau of Standards.

From this table it will be noted that a coefficient "C" is given, which is the overall transmission of heat based on a unit of time, surface, thickness and temperature difference or B.t.u. per hour per square foot per inch of thickness per degree F. As the heat transfer is practically proportional to the thickness, the fundamental law can be expressed in a very simple formula:

$$\text{(1) Transmission in B.t.u./Hr.} = \frac{\text{“C”}}{\text{thickness}} \times \text{average sq. ft.} \times \text{temperature difference}$$

From the foregoing it will be noted, that if the temperature and area of a transmitting surface are known and held constant, the heat transfer depends upon conduction, radiation and convection.

TABLE XCII.—INTERNAL THERMAL CONDUCTIVITIES OF VARIOUS MATERIALS (C)*

Material	Description	B.t.u. per 24 hours	B.t.u. per hour	Lb. per cu. ft.
Air	Ideal air space	4.2	0.175	0.08
Air Cell, ½ inch	Asbestos paper and air spaces	11.0	0.458	8.80
Air Cell, 1 inch	Asbestos paper and air spaces	12.0	0.500	8.80
Aluminum	Cast	24.000	1000.000	162
Ammonia Vapor	32° F.	3.19	0.133	0.21
Aqua Ammonia	64° F.	75.90	3.160	56.50
Asbestos Mill Bd.	Pressed asbestos—not very flexible	20.00	0.830	61.00
Asbestos Paper	Asbestos and organic binder	12.	0.500	31.0
Asbestos Wood	Asbestos and cement	65.0	3.700	123.0
Balsa Wood	Very light and soft—across grain	8.4	0.350	7.5
Boiler Scale		305	12.700	......
Brass		15.000	625.000	250.
Brick	Heavy	120	5.000	131.
Brick	Light, dry	84	3.500	115.
Brine	Salt	27.1	1.130	73.4
Cabot's Quilt	Eel grass enclosed in burlap	7.7	0.321	16.0
Calorax	Fluffy finely divided mineral matter	5.3	0.221	4.0
Celite	Infusorial earth powder	7.4	0.308	10.6
Cement	Neat Portland, dry	150.0	6.250	170.
Charcoal	Powdered	10.0	0.417	11.8
Charcoal	Flakes	14.6	0.613	15.0
Cinders	Anthracite, dry	20.3	0.845	40.0
Concrete		125.0	5.200	136.0
Concrete	Of fine gravel	109.0	4.540	124.0
Concrete	Of slag	50.0	2.080	94.5
Concrete	Of granulated cork	43.	1.790	7.5
Copper		50.000	2083.000	556.0
Cork	Granulated ⅛-3/16 inch	8.1	0.337	5.3
Cork	Regranulate 1/16-⅛ inch	8.0	0.333	10.0
Corkboard	No artificial binder—low density	6.7	0.279	6.9
Corkboard	No artificial binder—high density	7.4	0.308	11.3
Cotton Wool	Loosely packed	7.0	0.292	......
Cypress	Across grain	16.0	0.666	29.0
Fibrofelt	Felted vegetable fibers	7.9	0.329	11.3
Fire Felt Roll	Asbestos sheet coated with cement	15.0	0.625	43.0
Fire Felt Sheet	Soft, flexible asbestos sheet	14.0	0.583	26.0
Flaxlinum	Felted vegetable fibers	7.9	0.329	11.3
Fullers Earth	Argillaceous powder	17.0	0.708	33.0
Glass		124.0	5.160	150.0
Glass		178.0	7.420	185.0
Granite		600	25.000	166.0
Granulated Cork	About 3/16 inch	7.5	0.313	8.1
Gravel	Dry, coarse	62.0	2.582	115.0
Gravel	Dry, fine	39.0	1.630	91.25
Ground Cork		7.1	0.294	9.4
Gypsum Plaster		54.0	2.250	......
Hair Felt		5.9	0.246	17.0
Hard Maple	Across grain	27.0	1.125	44.0
Ice		408	17.000	57.4
Infusorial Earth	Natural blocks	14.0	0.583	43.0
Insulex	Asbestos and plaster blocks—porous	22.0	0.916	29.0
Insulite	Pressed wool pulp—rigid	7.1	0.296	11.9
Iron	Cast	7.740	321.500	450.0
Iron	Wrought	11.600	483.000	485.0
Kapok	Imp. vegetable fiber—loosely packed	5.7	0.238	0.88
Keystone Hair	Hair felt confined with building paper	6.5	0.271	19.0
Limestone	Close grain	368	15.300	185.0
Limestone	Hard	214.0	9.330	159.0

*From "Principles of Refrigeration," Nickerson & Collins Co., Chicago.

TABLE XLII.—INTERNAL THERMAL CONDUCTIVITIES OF VARIOUS MATERIALS (C)—(CONTINUED)*

Material	Description	B.t.u. per 24 hours	B.t.u. per hour	Lb. per cu. ft.
Limestone	Soft	100.0	4.167	113.0
Linofelt	Vegetable fiber confined with paper	7.2	0.300	11.3
Lithboard	Mineral wool and vegetable fibers	9.1	0.379	12.5
Mahogany	Across grain	22.0	0.916	34.0
Marble	Hard	445	18.530	175.0
Marble	Soft	104	4.330	156.0
Mineral Wool	Medium Packed	6.6	0.275	12.5
Mineral Wool	Felted in blocks	6.9	0.288	18.0
Oak	Across grain	24.0	1.000	38.0
Paraffin	"Parowax," melting point 52° C.	38.0	1.582	56.0
Petroleum	55° F.	24.7	1.030	50.0
Plaster		132.0	5.500	105.0
Plaster	Ordinary mixed	90	3.750	83.5
Plaster	Board	73	3.040	75.0
Planer Shavings	Various	10.0	0.417	8.8
Pulp Board	Stiff pasteboard	11.0	0.458	......
Pumice	Powdered	11.6	0.483	20.0
Pure Wool		5.9	0.246	6.9
Pure Wool		5.9	0.246	6.3
Pure Wool		6.3	0.263	5.0
Pure Wool		7.0	0.292	2.5
Rice Chaff		16.0	0.667	10.0
Rock Cork	Mineral wool and binder—rigid	8.3	0.346	21.0
Rubber	Soft	45	7.875	94.0
Rubber	Hard, vulc	16.0	0.667	59.0
Sand	River, fine, normal	188.0	7.830	102.0
Sand	Dried by heating	54.0	2.250	95.0
Sandstone		265	11.100	138.0
Sawdust	Dry	12.0	0.500	13.4
Sawdust	Ordinary	25.0	1.040	16.0
Shavings	Ordinary	17.0	0.707	8.0
Silicate Cotton		14.0	0.583	8.55
Slag Wool		18.0	0.750	15.0
Snow on Ref. Coils		75	3.130	......
Tar Roofing		17.0	0.707	55.0
Vacuum	Silvered vacuum jacket	0.1	0.004	.....
Virginia Pine	Across grain	23.0	0.958	34.0
Water	Still, 32° F.	100	4.166	62.4
White Pine	Across grain	19.0	0.791	32.0
Wool Felt	Flexible paper stock	8.7	0.363	21.0

Conduction.—Heat transfer by conduction occurs by means of molecular transmission due to the different intensities of irregular vibration of the molecules, causing the higher temperature or more rapid moving molecules to strike the lower temperature or slower moving molecules and cause them to move at the same rate. Due to friction, adhesion, etc., the intensity decreases as it passes from the faster to the slower molecules. The interchange of heat in this way may occur between different parts of the same body or between two separate bodies in actual contact.

When one end of a bar of iron is held in a fire the other end will soon become too hot to hold in the hand. The heat

has been transferred by conduction. One end of a wooden stick can be held in the fire without the other end becoming warm. In general, metals are good conductors, while lighter weight materials are poor conductors, so that comparative transmission can be made from their densities. A recent theory for the better insulating properties of substances containing air cells, is that there is a very intense atomic resistance at the junction of a solid and gas, thus offering greater retardation to the molecular activity transfer.

Radiation.—Radiation is the transfer of heat by means of continuous and irregular ether vibrations and the transformation, in whole or in part, of the energy of light into heat energy by impact upon the surface of a substance. It is an electromagnetic phenomenon, in which the longest heat waves are about 0.042 centimeters while the shortest solar waves that can pass through the atmosphere are 0.00003 c.m. The range of the radio waves is about 3 meters to 20,000 meters. When heat or solar radiation strikes a body it is in general partly reflected, partly absorbed and partly transmitted. The part which is transmitted is nil in case of metals, unless they are made into exceedingly thin almost transparent foils, it is very small in case of water and ice and large in case of quartz, rock salt, etc. Thus in most practical cases part of the radiation is absorbed and part of it reflected, the amount of which is smaller the more dull and black the surface is. In the ideal limiting case which is closely approached by lampblack, the entire amount of radiation is absorbed.

The amount of heat transferred by radiation depends upon the character of the radiating surfaces; whether hot or cold, dark or light, temperature difference, absorbing properties, etc.

The blacker an object the more heat it will lose by radiation. Stoves and radiators intended to give out heat should be black. Cooking utensils, coffee urns, etc., should be bright, (tinned or nickeled) in order to lose as little heat as possible. A stove nickel plated all over will give out only about half as much heat as the same stove at the same temperature if black. A brightly tinned hot air furnace pipe may lose less heat than when covered with one or two layers of asbestos paper, as the surface of the asbestos paper radiates heat much

more rapidly than the bright tin. The pipe should be black to prevent radiation to the inside surface of the asbestos paper, then the asbestos would be more effective. If asbestos paper of sufficient thickness is used, it will save heat, even on bright tin pipes.

Further it has been found experimentally that a body as it is heated radiates heat waves the amount of which is equal to the amount absorbed. The table below gives the radiating and absorbing power, and the reflecting power of a few common substances. It may be noted here that the radiating power is also called the emissivity.

TABLE XLIII.—HEAT ABSORBING, RADIATING, AND REFLECTING POWER OF SUBSTANCES

Substances	Absorbing & Radiating Power	Reflecting Power
Black body	1.00	0.00
Glass	0.90	0.10
Ice	.85	.15
Polished Cast Iron	.25	.75
Polished Wrought Iron	.23	.77
Polished Brass	.07	.93
Copper Hammered	.07	.93
Silver Polished	.03	.97

According to Prevost's theory of heat exchanges a warm body radiates more heat to the surrounding cold bodies than it receives from them and thus its temperature drops, while a cold body also radiates heat but it radiates less than it receives, and, therefore, its temperature rises. According to this theory, a body in a refrigerator placed near the ice radiates heat no faster than it would to a warmer body, but it receives less from the ice in return and, therefore, becomes colder.

It is well established that the heat exchange by radiation between two bodies is given by:

$$H = E\,(T_2^4 - T_1^4) \times 16 \times 10^{10}$$

Where H = B.t.u. per sq. ft. per hour.

T_1 & T_2 = Absolute Temperatures of the two bodies in degrees F.

E = An empirical constant called the emissivity of the surface considered: $E = 1$ for a black body.

Radiation Between the Sun and the Earth.—The heat and light from the sun come to us through space in a form of wave motion called radiation. The atmosphere offers considerable

obstruction to the passage of these waves. Even when the sky is very clear, rarely more than 65 per cent of the radiation penetrates to the surface of the earth, the part absorbed being expended in raising the temperature. The region near the upper limits of the atmosphere is one of intense cold. As the sun, having a much higher temperature than earth, radiates heat to the earth, so from the surface of the earth, heat is radiated to the much colder upper limits of the atmosphere.

The radiation of heat from the earth is continuous both day and night when there are no clouds or other obstruction between the earth and the upper atmosphere. During the day the amount of heat received from the sun is so much greater than the amount lost by radiation from the earth, that the temperature rises. After the sun sets, however, no heat is received to counterbalance the loss by outgoing radiation and the temperature falls.—(U. S. Department of Agriculture, Farmers' Bulletin, No. 1096).

Convection.—Convection is the transfer of heat by displacement of movable media; the heated medium moves and carries the heat energy with it. In other words heat is carried from one place or object to another by means of some outside agent, such as air or water or any moving gas or fluid. The hot air and hot water heating systems work on this principle. For example, in case of an ordinary household radiator, steam or hot water heats the radiator and it establishes a temperature differential between the metal and the adjacent layer of air, the layer of air is heated and consequently its density is reduced as compared to the cooler layers of air. Thus the denser and cooler particles of air begin to descend while the warmer and less dense particles begin to rise and a natural upward movement of heated particles sets in. If desired, however, the movement of these heated particles can be accelerated and the heat transfer greatly increased by means of a fan or blower. In the first instance we have natural convection and in the second forced convection. It is also clear that the increased heat transfer secured in the latter case is produced by the external mechanical work supplied and here as in all other engineering work we pay for what we receive.

The food and containers in a refrigerator are cooled mostly by convection. The circulating air is the medium used to transfer the heat from the food and walls of the food compartment to the ice. This process of heat transfer is continuous. The air in passing through the food compartment absorbs sufficient heat to increase its temperature about 10° F.

It is well known in a general qualitative way that heat flow by forced convection between a metal surface and a fluid depends upon the following:

1—The velocity of the fluid; the higher the velocity the higher the heat flow.

2—The temperature difference between the metal and the fluid; the higher this difference the higher is the heat flow.

3—The thermal conductivity of the fluid.

4—Diameter of the tubes around or in which the fluid is assumed to flow.

5—The density of the fluid.

6—The viscosity of the fluid.

7—The depth or length of the device measured along the path in which the fluid flows.

8—The temperature difference between fluid and body.

9—The character of the surface.

The values given in Table XLIV are for inside surface only, and are represented by the symbol K. Due to the more exposed outside surface and rapid movement of air, the coefficient for this is much larger, generally 2½ to 3 times, so that K_2 can be used as 3 times K.

TABLE XLIV.—COEFFICIENTS OF RADIATION AND CONVECTION IN B.T.U. PER HR. PER ° F. SQ. FT.

University of Illinois Engineering Experimental Station.

Brick Wall	1.40	Glass	2.00
Concrete	1.30	Tile plastered on both sides	1.10
Wood	1.40	Asbestos board	1.60
Corkboard	1.25	Sheet asbestos	1.40
Magnesia board	1.45	Roofing	1.25

Comparison of Heat Insulators.—Table XLV gives a comparative idea of the thermal conductivity of insulators used in household cabinets. Air which cannot circulate and carry heat in that way (by convection) is one of the best heat insulators

to be found. Cotton, wool, feathers, cork, etc., are good insulators because they contain a large amount of air in the cells or in the spaces between the fibers. Clothing keeps in the heat of the body chiefly because it contains air between the layers and in the meshes of the cloth. When the enclosed warm air is displaced and is replaced by colder air, as is the case in windy weather, the clothing no longer keeps one so warm.

TABLE XLV.—COMPARISON OF THERMAL CONDUCTIVITY OF HEAT INSULATING MATERIALS USED FOR INSULATING HOUSEHOLD REFRIGERATORS

Material	Relative Thermal Conductivity
Vacuum jacket silvered	1
Mineral wool (medium packed)	66
Corkboard (low density)	67
Ground cork (ordinary)	71
Vegetable fibre (Linofelt)	72
Granulated cork (about 3/16 inch)	75
Eel grass (enclosed in burlap)	77
Balsa wood (medium weight)	92
Planer shavings	100
White pine (across grain)	190
Oak (across grain)	240

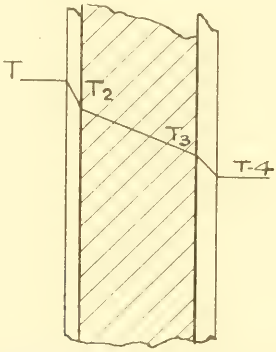


FIG. 4.—SHOWING RADIATION AND CONVECTION LOSSES.

If the clothing is close-fitting, there is less room for an air layer between the layers of the clothes and therefore, it is less warm.

To keep warm in cold, windy weather, the clothing should consists of loosely fitting garments, preferably of wool, with

some outside wrap which is nearly windproof, such as a very close woven cloth, or even leather or rubber. A fur coat is very much warmer if the fur is on the inside, where the wind cannot disturb the air which is held among the hairs.

Determination of Heat Loss Through a Wall or Refrigerator.—As shown in the previous paragraphs, heat is transmitted through a substance from higher regions to a lower region by means of conduction, radiation, and convection. Referring to Fig. 4 it can readily be seen that the drop from T_1 to T_2 is radiation and convection losses from the outer surface,

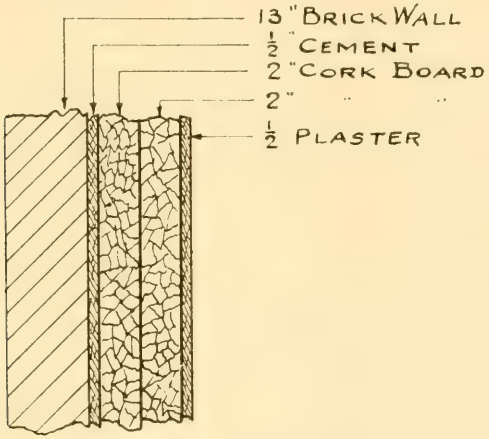


FIG. 5.—STANDARD WALL.

T_2-T_3 the losses or transmission by conduction through the material, and T_3-T_4 convection and radiation from the cold air in the box to the inner surface. The convection and radiation drop is caused by a very thin layer or surface film surrounding each surface.

Fig. 5 shows a standard wall as used in many cold storage buildings and ice storages. The unit transmission through the combination wall can very easily be determnied from the following formula:

$$\text{B.t.u./ sq. ft./hr./}^\circ\text{MD} = \frac{1}{\frac{1}{K_1} + \frac{X}{C} + \frac{X}{C_1} + \frac{X}{C_2} + \frac{1}{C_3}}$$

X being the thickness of the material, C the unit coefficient for each material as in Table XLII, K_1 and K_2 surface coefficients for the inner and outer surfaces respectively.

$$\text{Substituting—B.t.u./sq.ft./hr./°MD} = \cfrac{1}{\cfrac{1}{1.10} + \cfrac{13}{5} + \cfrac{4}{.279} + \cfrac{1}{6.25} + \cfrac{1}{4.2}}$$

If this value is now used as the factor $\frac{\text{“C”}}{\text{thickness}}$ in the fundamental formula (1) given on page 101 the total heat leakage through the walls can be obtained. It has been found that the resistance to heat flow at the surface, due to radiation and convection is very small in comparison to internal thermal conductivity of the material itself, so that these two factors can be omitted, particularly when good insulation of normal thickness is used. This can be demonstrated by the omission of the factors K_1 and K_2 in the above formula resulting in a final value of .0585 instead of .0548 or 6¾% greater.

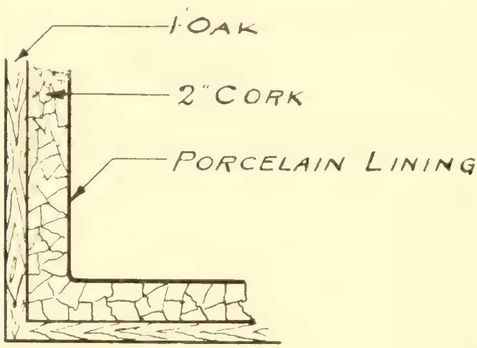


FIG. 6.—CROSS SECTION OF A STANDARD ICE BOX.

Referring to Fig. 6, a cross section of a standard ice box is given. Assuming this to be a 9 cu. ft. refrigerator the outside surface would be 54 sq. ft. and the inside surface 34.5 sq. ft. or an average of 44.25 sq. ft.

The unit heat transmission would be

$$\cfrac{1}{\cfrac{2}{.279} \quad \cfrac{1}{1}} = .1225 \text{ B.t.u./sq. ft./°MD/ hr.}$$

Substituting in our fundamental formula for $\frac{\text{“C”}}{\text{thickness}}$

$$\text{B.t.u./hr.} = .1225 \times 44.25 \times 1^\circ = 5.42$$

Actual tests on this box gave 5.75.

For practical results to obtain the compressor load, 50% should be added for opening door, warm edibles, making ice, etc.

Insulation.—The most important factors entering into the choice of an insulator are as follows:

1. Thermal conductivity.
2. Odorless and sanitary.
3. Compact.
4. Vermin and fire resistant.
5. Not easy to disintegrate or settle.
6. Durable in service.
7. Reasonable in cost.
8. Structurally strong and easy to ship, handle, and install.
9. Conform to variation on surface of lining.

1. Thermal Conductivity.—The best insulator that could possibly be found would be one that was an absolute non-conductor of heat. Since this has not been discovered as yet we must content ourselves with insulation which are good non-conductors, or in other words, transmit heat at a very slow rate. As heat loss through an insulated wall is a continuous process, it must be the aim to reduce this loss to a minimum by increasing the thickness to a maximum commensurate with desired results. This is a question of first or initial cost.

2. Odorless and Sanitary.—Since ordinary food products are stored in the refrigerator, it is evident that the insulation should be absolutely free from mould, rot, or odor and perfectly sanitary. The interior surfaces should be so constructed that they can be washed with water without effecting the insulation.

3. Compactness.—An insulation in order to be favorably considered must be compact or occupy a small amount of space for the equivalent heat loss prevention. If it can be made very thin, but at the same time give as good insulating value as

another 2 to 3 times as thick, it would naturally be given preference.

4. Vermin and Fire Resistant.—A desirable insulation should be of such nature that it will exclude vermin of all kinds, and should lend itself to fireproof construction of buildings. It should be slow burning and fire retarding and should not support a flame.

5. and 6. Not Easy to Disintegrate or Settle.—The durability of insulating materials depends upon the life of the materials used in their manufacture, the mode of manufacture and the waterproofness.

The insulation of a refrigerator is called upon to withstand constant changes of temperature and humidity. The ordinary refrigerator using ice usually has a rather poor water insulating material to protect the insulation. The greatest trouble is experienced around the ice compartment where water vapor will condense on the outside surface of the lining or rather between the lining and the insulation. If the insulation is installed very tightly against the lining, this condition is not likely to cause trouble. Moisture not only causes the insulation to deteriorate rapidly, losing to a large extent in heat insulating properties, but also may rust the lining and absorb food odors which will make the refrigerator very insanitary.

The moisture problem is especially important on mechanical refrigerators where freezing temperature or temperature below 32° F. are maintained in part of the cabinet. In this case a much lower room humidity will deposit moisture on the lining. There are very few ice refrigerators constructed which are insulated in a suitable manner to be used for the lower temperatures as usually supplied by mechanical refrigerating machines.

7. Reasonable in Cost.—An insulation to be universally used depends on such factors as a reasonable initial cost of material, cheap installation cost, minimum of repair charges, as well as a minimum amount of space for maximum retardation of heat flow.

8. Structurally Strong and Easy to Ship, Handle and Install. — Insulation should be compact and structurally strong so that it may be used in walls, ceilings, and floors of any type of construction. It should have sufficient strength to allow for shipment and for installation by ordinary workmen. These factors determine to a large extent, its application commercially.

9. Conform to Variations on Surface of Lining.—Due to unevenness of surfaces on which insulation is to be placed it is essential that elasticity, to a certain extent, be embodied in the insulator, or otherwise there will be resultant breaks when the non-flexible insulation is jammed against an uneven surface.

Air Spaces.—Many refrigerators use air spaces for insulation. Heat may be transferred across an air space by all three methods of heat transfer: radiation, convection and conduction.

A very high vacuum is necessary to appreciably lower the rate of heat transfer by convection. The heat transfer by convection is greater when there is a large temperature drop, as the air will then circulate more rapidly, carrying heat from one wall to the other.

Air is a very poor conductor of heat when compared with the usual insulating materials used in refrigerators. The conductivity B.t.u. per day per sq. ft. per deg. F. per inch thickness for various materials is given as follows:

Air, if radiation and convection could be prevented	4.2
Mineral wool	6.6
Corkboard	6.7
Flaxlinum	7.9
White pine	19.0
Oak	24.0

This tabulation shows that the amount of heat transferred across air space by conduction is relatively low.

The amount of heat passing over an air space by radiation is very large when there is a large temperature differential between the two walls. The rate of heat transfer by radiation is proportional to the fourth power of the absolute temperature of the surface, enclosing the air space, providing the surfaces

are perfect radiators or absorbers. The blacker the object the more heat it will lose by radiation. Bright tinned or nickeled objects lose very little heat by radiation. The vacuum bottle usually has bright polished surfaces to prevent heat entering the walls by radiation.

The United States Bureau of Standards gives the following tabulation on the heat conduction of air spaces, in which A is the width of the air space in inches, B is the heat conduction expressed in B.t.u. per square foot per degree F. per 24 hours for the corresponding thickness stated, and C, the heat conduction expressed in B.t.u. per square foot per degree per 24 hours per inch thickness:

A	B	C
1/8	50	6.3
1/4	32	8.1
3/8	26	9.8
1/2	23	11.6
5/8	22	13.6
3/4	22	16.4
7/8	22	20
1	22	22
2	21	43
3	21	62

The insulating value of air spaces is not proportional to the thickness of the spaces.

The heat loss between walls of materials such as wood, paper, etc., by radiation alone, is about 20 B.t.u. per day per square foot per degree F. for ordinary temperatures. At higher temperatures, the radiation loss is still larger. Air spaces are not good insulators on account of this radiation loss. This large heat loss by radiation may be greatly reduced by using polished surfaces for the walls between the air spaces. Perhaps the best way to reduce this loss is to use an insulating material such as cork, which eliminates the heat loss by radiation almost entirely.

One authority describes the use of a heat insulating material such as corkboard, as an air space insulation composed of an almost perfect heat radiation screen. Each air cell in the cork must radiate heat from one wall to another and as the temperature differential is small, the amount of heat transferred by radiation is nearly negligible.

Insulating Effect of Air Spaces.—The insulating effects of air spaces, according to various authorities are given in Table XLVI. The effects are given in conductivities, expressed in B.t.u. per square foot per twenty-four hours per degree of temperature difference for various thicknesses of air spaces. It will be noted that the increasing of the thickness of the air space above a certain amount does not proportionately decrease the total conductivity.

TABLE XLVI.—INSULATING EFFECT OF AIR SPACES

Authority	Thickness Inches	Conductivity B.t.u. per sq. ft. per 24 hrs. per Deg. Fahr. Temp. Diff.	Remarks
Prof. L. A. Harding, Pennsylvania State College	1 to 6	39.8	
Refrigerating World	1	30.0	
Prof. A. C. Willard, Railway Age Gazette	4	38.2	
Nusselt	¾		Spaces greater give no additional value.
Willard & Lichty University of Illinois	½	42.5	Single and double box test.
U. S. Bureau of Standards	⅓	11.0	Corrugated asbestos paper enclosing air space.
U. S. Bureau of Standards	⅛	50	Air spaces bounded by sheets of insulating paper.
	¼	32	
	⅜	26	Air spaces not wider than ⅜ inch retard heat about as well as an equal thickness of sawdust.
	½	23	
	⅝	22	
	¾	22	A 3 inch air space has nearly the same value as as 1 inch space.
	⅞	22	
	1	22	
	2	21	
	3	21	
U. S. Bureau of Standards	1	4.2	No heat transferred by radiation or conduction
Pennsylvania State College	3 in. spaces	5.36	Three air spaces.
Wood & Grundhofer	½ in. each	7.68	
	3 spaces 1 in. each	5.28	
		5.29	Three air spaces.
		4.26	

Comparison, if 3 air spaces ½ in. each = 100%
Then 2 air spaces ½ in. each = 79%
and 1 air space ½ in. each = 59%
Comparison, if 3 air spaces 1½ in. each = 100%
Then 3 air spaces 1 in. each = 88%
and 3 air spaces ½ in. each = 70%

Types of Insulating Material.—As can be noted in Table XLII, many kinds of materials can be used for insulation. The most commonly used materials are corkboard, granulated cork, ground cork, mineral wool, rock cork, hair felt, kapok, lithboard, sawdust and shavings.

Cork.—Cork is the outer bark of a tree growing on the Spanish Peninsula and in Northern Africa. In its natural state, it is composed of a large number of minute air cells, separated by thin walls.

Corkboard is made by compressing pure granulated cork in molds and baking. The baking process improves the insulating value, first by driving off the sap, thus increasing the volume of confined air; second, by coating the surface of each separate granule with a thin film of the natural waterproof gum or rosin, which cements the whole mass together firmly. After the baking process, the boards are trimmed to size. Pure cork contains 43% wood fibre and 57% entrapped air.

A cheaper and inferior grade of corkboard may also be manufactured. In this process, granulated cork is mixed with hot asphalt and pressed into sheets.

The boards are 12″x36″ and are supplied in thicknesses 1-1½-2-2½-3-4-6″. The weight varies from 7 to 12 lbs. per cubic foot, depending on the process. Regranulated cork of 8-20 mesh or fineness weighs 11 lbs. per cubic foot, and coarse granulated weighs 5 to 6 lbs. per cubic foot. The regranulated is baked and is made from savings trimmed from corkboard.

Because of its cellular structure, cork has little capillary attraction, which together with the coating of waterproof gum for binder, makes it practically impervious to moisture. It possesses essentially all of the requirements previously cited for a good commercial insulator and is therefore the most universally used.

Mineral Wool.—Mineral wool is a vitreous substance made of limestone which is melted at 3000° F. and then blown into fine fibres by high pressure steam. It is a soft, pliable and elastic material resembling wool or cotton, and due to the fibres crossing and interlacing in every direction small air spaces are formed which produce its insulating properties. Mineral wool boards are made by mixing the wool with a paraffin wax binder and other ingredients and then compressing it into sheets. These are usually 16x36 inches and are made from ½ to 3 inches in thickness. The weight is approximately 18 lbs. per cubic foot in boards, but only 12½ lbs. when loosely

packed. The board contains about 90 per cent mineral wool and 10 per cent binder and consists of approximately 80 per cent entrapped air. Mineral wool board possesses many of the essentials of a good insulator but is inferior to corkboard as to structural strength, fire retardation and installation cost.

Flaxlinum or Linofelt.—This is a flax fiber product pressed into a continuous sheet and covered with a waterproof charcoal sheathing. It is customary to use two sheets of flaxlinum with a dead air space between them. This insulation is also made in .quilted sheets which are held in place by wooden strips.

Mineral Felt.—Mineral felt is a combination of mineral wool, asbestos, and hair felt. It is claimed that this material will not settle like other loose feltings.

Balsa Wood.—Balsa wood is being used to some extent for insulation on refrigerators. Its peculiar structure and qualities which make it suitable for this purpose were first realized about 1915.

The tree grows in certain parts of South America and the West Indies. It grows very rapidly to a height of from thirty to sixty feet and a diameter of from twelve to fifteen inches in four or five years. This rapid growth is probably the cause of the peculiar structure of the wood. The cells are large and remote from one another, and the cell walls are exceedingly thin, while in most other woods the cells are small, close together and have fairly thick walls. The balsa tree is now being cultivated in artificial groves. Balsa is a second growth wood which is always found in clearings. The trees seldom grow closely together.

In the natural state, balsa wood is not suitable for insulating material. Colonel Marr discovered a method of treating the wood which renders it waterproof, prevents rot and keeps it from changing shape. This process is a bath composed mostly of paraffin, performed in such a way that the interior cells are coated without clogging up the porous structure.

Lithboard.—Lithboard consists of mineral wool and vegetable fibers. It is made into boards by using a waterproofing

binder and compressing. These boards have a composition of approximately 40 per cent vegetable fibres (flax) and 60 per cent mineral wool, and are generally 18″x48″ with a thickness of ½ to 3″. It weighs about 12½ lbs. per cubic foot.

Rock Cork. — Indiana limestone with a certain specified content is heated up to 2800° F. and passed through a "V" shaped steam jet. The heavier particles of blown rock drop off right at the nozzle and are separated from the rock wool that is picked up from the blowing chamber. This rock wool still has some very small particles of blown rock in it. The rock wool is taken to an agitator and here the rest of the particles are removed. The rock wool now is mixed with an oil asphalt and some paper stock, at approximately 200° F. Water is introduced and acts as a carrier agent for the mixture. The mixture is poured into moulds, that have screens in the bottom through which it drains, and the mixture is allowed to settle. After the water has drained off the mould goes to a drying kiln and stays there for about 72 hours.

Rock cork does not undergo any sort of compression during the moulding process other than that due to its own weight. The rock cork now is in slabs and is planed down to any required thickness as desired. Rock cork weighs approximately 16 to 20 lbs. per cubic foot and possesses many of the requirements of a good insulator.

Selection.—In selecting an insulation for a proposed installation a number of factors must be taken into consideration:

1. Type of construction
2. Character of refrigerated products
3. Temperatures to be maintained
4. Thickness of walls
5. Location of plant.

The following table gives the most economic thickness of corkboard and other insulation of same unit transmission:

—20° to —10°	8″
—10° to — 0°	6″
0° to 15°	5″
15° to 35°	4″
35° to 45°	3″
45° and above	2″

Heat Transfer in Apparatus.—The heat transfer taking place in a refrigerating apparatus is similar to that occuring through insulation, in that the flow occurs from a region of high temperature to a region of low temperature. Whereas, a very slow rate of infiltration through insulation was desired just the reverse is true in the apparatus; the fastest possible transfer is wanted. Generally this transfer of heat is accomplished between two fluids separated by a solid wall of good conductivity.

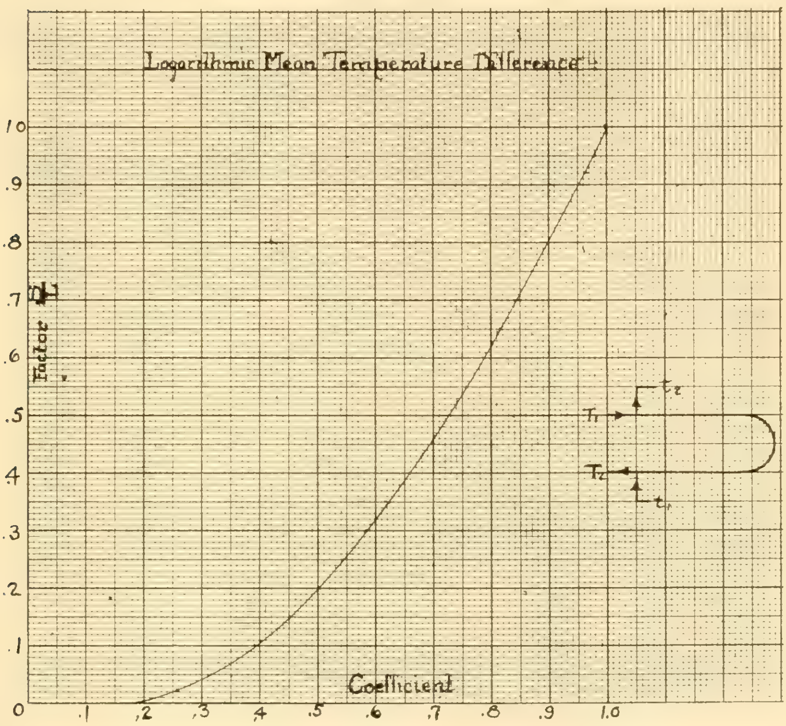


FIG. 7.—MEAN TEMPERATURE DIFFERENCE CURVE.

Since the heat transfer may occur by means of conduction, radiation or convection, the fundamental law of heat transfer holds, the same as for insulation; although the unit transmission as determined by experiment combines all three methods, as well as the kind of material and thickness of separating wall. The formula then becomes—(2).

B.t.u./hr. = "C" x sq. ft. of surface × temperature difference. (C is given in Table XLVIII.)

The *mean* temperature difference for apparatus is somewhat different than for insulation due to the fact that the temperatures on both sides of the insulation are comparatively constant, whereas in the apparatus they are changing constantly. Therefore in the first case an arithmetic degree mean difference can be used but a logarithmic mean temperature difference must be found in the latter case.

Due to the character of the formula as given by Hausbrand and its attendent higher mathematics this logarithmic degree mean difference method has been put in a simple curve form, making it available to everyone.

TABLE XLVII.—THICKNESS OF INSULATION FOR COLD PIPES

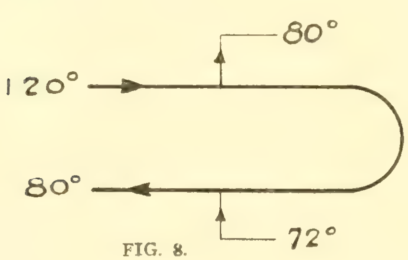
Thickness of Cork	For Use With	For Temperatures
1½ in.	Ice water, liquid ammonia, brine and other cold lines.	Above 25° F.
2 in. to 3 in.	Brine, ammonia and other cold lines.	0° to 25° F.
3 in. to 4 in.	Brine, ammonia and other cold lines.	Below 0° F.

T_1 = Inlet temperature of substance to be cooled
T_2 = Outlet temperature of substance to be cooled
t_1 = Inlet temperature of cooling substance
t_2 = Outlet temperature of cooling substance
$T_1 - t_2$ and $T_2 - t_1$ = Differences
S = Smallest difference
L = Largest difference

Factor $\frac{S}{L}$ = Ordinate

Coefficient obtained from Curve = Abcissa
Coefficient × largest difference = Mean temperature difference.

Example: To cool milk from 120° to 80° with 72° water heated to 80° during the process.



$$\frac{S}{L} = \frac{8}{40} = .2$$

FIG. 8.

Running across on the .2 factor line to the curve and then projecting down at right angles the coefficient .5 is obtained. Then the mean temperature difference is $.5 \times 40 = 20$.

If an arithmetical degree *mean* difference had been used the result would have been the difference of average temperatures of

$$\frac{(120 + 80)}{(\ 2\ )} - \frac{(80 + 72)}{(\ 2\ )} = 24$$

which would have been a 20 per cent error.

It has been found that for all practical purposes if $\frac{S}{L}$ is greater than .5 an arithmetic degree *mean* difference can be used.

Coefficients of Heat Transfer in Apparatus. — In table XLVIII is given overall unit heat transfer coefficients, as determined by experiments. They hold good for the general wall thicknesses found in refrigerating apparatus and when the surface is comparatively free from frost scale, oil and other foreign matter.

The best heat transfer is obtained from liquid to liquid followed by liquid to gas and the worst transfer is from gas to gas. Copper has a considerably higher rate of transfer than steel while lead is very much worse than either. Some important factors on which the rate of heat transfer depends are:

1. Velocity of fluids
2. Density and kinds of fluids
3. Temperatures at which they are handled
4. Thickness and material of separating wall
5. Smoothness and cleanliness of wall as regards foreign substances, material, as well as gases.

As an example to show the amount of steel pipe to be installed in a small storage box having a load factor of 3000 B.t.u. hr. and held at a temperature of 40° with 15° average expansion through the coil, using the fundamental formula (2):—

$$3000 = 2.5 \times \text{sq. ft.} \times (40—15)$$
$$\text{sq. ft.} = 48.$$

TABLE XLVIII.—HEAT TRANSFER COEFFICIENTS, IN B.T.U. PER HOUR PER SQ. FT. PER DEGREE TEMP. DIFF.*

Heat Transfer From	Heat Transfer To	Apparatus	Heat Transfer Coefficient	Mean Temperature Difference	Conditions
Gas Cooling	Liq. Boiling	Direct Exp. Coils	2.5	20° F.-up	Gravity Air Circulation—About 180′ per min.
Gas Cooling	Liq. Boiling	Direct Exp. Coils	2.0	15°–19°	Gravity Air Circulation—About 120′ per min.
Gas Cooling	Liq. Boiling	Direct Exp. Coils	1.5	10°–14°	Gravity Air Circulation—About 90′ per min.
Gas Cooling	Liq. Warming	Brine Coils	3.5	20° up	Gravity Air Circulation—About 180′ per min.
Gas Cooling	Liq. Warming	Brine Coils	3.0	15°–19°	Gravity Air Circulation—About 120′ per min.
Gas Cooling	Liq. Warming	Brine Coils	2.5	10°–14°	Gravity Air Circulation—About 90′ per min.
Liq. Cooling	Liq. Boiling	Holdover Brine Tank	1.25	20°–up	Direct Expansion
Liq. Cooling	Liq. Boiling	Holdover Brine Tank	1.0	15°–19°	Direct Expansion
Liq. Cooling	Liq. Boiling	Holdover Brine Tank	0.75	10°–14°	Direct Expansion
Gas Cooling	Liq. Boiling	Direct Exp. Coils	3.0	10°–20°	Forced Air Circulation, 600′ per min.
Gas Cooling	Liq. Warming	Brine Coils	4.5	10°–20°	Forced Air Circulation, 600′ per min.
Liq. Cooling	Liq. Boiling	Ice Tank Coils	10.0	14°–18°	No Brine Agitation
Liq. Cooling	Liq. Boiling	Ice Tank Coils	13.0	14°–18°	Medium Brine Agitation—1 change in 10 min.
Liq. Cooling	Liq. Boiling	Ice Tank Coils	15.0	14°–18°	Rapid Brine Agitation—1 change in 5 min.
Liq. Cooling	Liq. Boiling	Brine Tank	10.0	10°–20°	Submerged Expansion Coils in Still Brine
Liq. Cooling	Liq. Boiling	Congealing Tank	8.0	10°–15°	Brine Congeals on Submerged Expansion Coils
Liq. Cooling	Liq. Boiling	D. P. Brine Cooler	80.0	10°	Velocity of Brine = 3′ to 4′ per second
Liq. Cooling	Liq. Boiling	Shell Brine Cooler	80.0	10°	Velocity of Brine = 4′ to 5′ per second
Liq. Cooling	Liq. Boiling	Water Cooler	12.0	30°	Water Circulated Over Subm. Expan. Coils
Liq. Cooling	Liq. Boiling	Water Cooler	20.0	....	Water Over Coils (Ammonia 12° F.)
Liq. Cooling	Liq. Boiling	Water Cooler	40 to 60	....	Water Flowing Over Pipes (Ammonia, 32° F.)
Vapor Cond.	Liq. Warming	D. P. Condenser	130.0	....	Counter-Current Flow Ammonia Condenser
Vapor Cond.	Liq. Warming	Atmos. Condenser	125.0	....	Counter-Current Flow Ammonia Condenser
Vapor Cond.	Liq. Warming	Atmos. Condenser	40 to 60	....	Parallel Current Flow Ammonia Condenser
Vapor Cond.	Liq. Warming	Submerged Cond.	30.0	....	Counter-Current Flow Ammonia Condenser
Liq. Cooling	Liq. Warming	D. P. Exchanger	80.0	....	Counter-Current Flow
Liq. Cooling	Liq. Warming	Water Cooler	30.0	....	Brine Coils in Circulated Water
Liq. Cooling	Liq. Warming	Water Cooler	60.0	....	Water Flowing Over Brine Coils

*From "Principles of Refrigeration," Nickerson & Collins Co., Chicago.

Since it takes 2.3 ft. of 1¼″ pipe to make 1 square foot of surface, it will be necessary to use $48 \times 2.3 = 110$ ft.

From the foregoing it can readily be seen that many refrigerating problems are really heat transfer problems, and can be solved by either formula—1 or 2.

CHAPTER VI

REFRIGERATING SYSTEMS.

History and Principles of Refrigerating Systems.—The following chapter is devoted to historical data and the general principles underlying the operation of the principal refrigerating systems. The air refrigerating machine works on a principle of cooling by the absorption of sensible heat, and was one of the first types given consideration. Absorption refrigerating machines were also given early consideration.

The inherent advantages of the compression refrigerating machine, in which advantage is taken of the latent heat of evaporization, were early recognized and this type of system, consequently, was subjected to development and perfection at an early date. A chemical method for producing refrigerating effects has been used for centuries, but of course, the commercial application of such methods is limited, on account of the high cost of producing such refrigerating effects.

Following a discussion of the refrigerating systems, attention is given to the requirements of a household system, in which special attention is devoted to the design and construction of the different component parts of such systems.

Gorrie Air Machine.—The first air refrigerating machine was invented by Doctor Gorrie at New Orleans about 1850. Air was compressed in a cylinder and delivered to a chamber which was immersed in the cooling water. The pressure in the chamber was maintained at about 15 pounds per square inch above the pressure of the atmosphere. Water injection

was used to partly cool the air during compression. Both air and water were delivered to the receiver. The air in the receiver was further cooled by the water on the outside. Then the air was expanded in another cylinder discharging at about atmospheric pressure. The expanding air was mixed with a quantity of brine which was injected into the expansion cylinder. The expanding air cooled the brine to about 20° F. This cold brine was used for ice making or refrigeration.

Kirk Air Machine.—Dr. Alexander Kirk invented a closed cycle air machine about 1861. This machine used a confined mass of air, operating always at pressure considerably above atmospheric pressure. Machines of this same type were made by Allen, an American, and Windhausen, a German.

Open Cycle Air Machine.—The open cycle air machine consists of two cylinders called a compression cylinder and an expansion cylinder. Air from the room which is to be cooled is taken in the compression cylinder. It is compressed and therefore warmed. This compressed air is then cooled by circulating water. This air is then made very cold by expansion to atmospheric pressure. Upon reaching this condition it is returned to the cold room.

Open cycle air machines of this type were proposed by Lord Kelvin and Professor Rankin about 1852. The first actual machine operating on this principle was made by Giffard in 1873. At a later date, machines of this type were made, namely the Bell-Coleman and other improved designs by Mr. Lightfoot, Messrs. Haslam and Hall.

The air machine has a relatively large power consumption and is only used to any large extent on ships.

Allen Dense Air Machine.—The dense air machine is used to some extent on boat installations.

In this system air is compressed to about 250 pounds and then cooled by the cooling water. This cooling is usually performed by a copper coil immersed in water.

The air is then passed through a moisture separator, after which it is conducted to the expansion cylinder. In this

cylinder the air is expanded to about 60 to 70 lbs. pressure and a very low temperature.

The 70 lbs. air is then passed through an oil separator before being returned to the compressor to start another cycle. A primer pump is used to automatically supply make up air.

Machines of this type require considerable attention to eliminate trouble from ice forming within the evaporator, due to freezing the water vapor supplied by the make up air. Lubrication is rather difficult on a machine of this type.

This system of refrigeration has not proven successful for small household machines, although the use of air as a refrigerant has some important advantages in this particular field of refrigeration.

Low Pressure Air Refrigeration System.—A recent development in household refrigerating machines operates on the principle of accelerating the evaporization of ammonia or alcohol by blowing air through the liquid.

The air is compressed by a blower to a pressure of 10 to 15 lbs. gauge. The blower is usually direct-connected to the motor and operates at motor speed.

This process is claimed to operate at efficiencies better than those obtained in the usual compression system.

Water Vapor Absorption Machines.—In the absorption type machine, two substances are used which have an affinity for one another so that one unites or dissolves in the other when they are cold, but they separate readily when heated. Sulphuric acid when cold has a great affinity for water. Heating a sulphuric acid and water mixture drives off water vapor. This vapor is condensed by the cooling water. The acid is then cooled and reabsorbs the water vapor at a low temperature and a very low pressure. There is a very low vacuum during both parts of the cycle. The absorbing substance acts like a pump and maintains a low pressure during the cooling cycle. This principle was first used by Professor Leslie in 1810. A small machine of this type was made by M. E. Carré in 1875 for household work. It consisted of an air pump, and a chamber to contain the acid. A rod on the pump handle served to agitate the surface of the sulphuric acid. Mr. Wind-

hausen made a large machine of this type in 1878. A small machine of this type is on the market at the present time, being manufactured by the Pulsometer Co., of Reading, Eng., and others.

Machines of this type have an overall thermal efficiency of about fifteen per cent which is lower than the compression type.

Ammonia Absorption Machines.—The ammonia absorption machine works on the principle of ammonia dissolving in water. One quart of water will dissolve about 500 quarts of ammonia gas. Ammonia has a higher vapor pressure than water and the absorbing is accomplished under a pressure considerably above atmospheric. Heating a water and liquid ammonia mixture drives off ammonia gas. This gas is condensed by the cooling water. The water is then cooled and reabsorbs the gas at a low temperature. In actual practice only part of the ammonia is driven off from the aqua solution.

The ammonia absorption machine was invented by F. Carré about 1858-1860. The original machine was a very crude affair, consisting merely of two vessels—one surrounded by cold water, the other containing the ammonia and water. The original patent in the United States was issued October 2, 1860, the reissue being dated February 18, 1873. The Carré machine, subsequently improved by Mignon and Rouart in France, Vass and Littmann in Germany, Reece, Mort, Nicolle, and others in England and Australia, marked a great era in mechanical refrigeration.

The Carré machine was the first one to obtain a foothold in the ice making industry in the United States. The first machine was shipped through the blockade in 1863 to Augusta, Ga., by Mr. Bujac of New Orleans. It was supposed to have a capacity of 500 pounds per day. Due, mainly, to the parties who had it in charge, the machine was not a success, and in 1866 it was shipped to Gretna, La., where it was run for exhibition and experimental purposes. Three other Carré machines, purchased by the firm of Bujac & Girarde, New Orleans, La., and installed in that city, also proved unsuccessful in operation.

In the fall of 1865, the firm of Mepes, Holden, Montgomery & Co. purchased the first of these machines and shipped it to San Antonio, Tex., and put it in operation under the supervision of D. L. Holden.

The absorption refrigerating machine is now manufactured by the Carbondale Machine Co., Columbus Iron Works, Henry Vogt Machine Co., York Manufacturing Co., and others in the United States. Messrs. Haslam and Hall now manufacture a machine of this type formerly developed by Messrs. Pontifex and Wood, in England. The overall thermal efficiency of the ammonia absorption system is about 25 per cent.

History of the Vapor Compression Machine.—The first machine of the vapor compression type was invented by Jacob Perkins, an American, and patented in England in August, 1834. It was further developed by Twining, who took out his English patent in 1850. This machine was not a commercial success.

It was not until 1857 that James Harrison of Geelong, Australia, made a compression machine using sulphuric ether which was of commercial value. Messrs. Siebe and Gorman later manufactured these machines in England. This refrigerant is not used today.

In April, 1867, Prof. P. H. Van der Weyde of Philadelphia, Pa., obtained patents for the use of naphtha, gasoline, petroleum, ether and condensed petroleum gas (chimogene) as refrigerants, and obtained patent on his compression refrigerating machine.

Mr. D. L. Holden, after his successful experience in San Antonio with the Carré ammonia absorption machine in 1865, purchased the patent rights of Prof. Van der Weyde and built his first compression machine at the Novelty Iron Works in New York City. Several other compression refrigerating machines using ammonia were built and installed by Mr. Holden in New Orleans, La., Bonham, Houston and Galveston, Tex.; Mobile, Ala.; Thibodauxville, La.; Selma, Ala., and Charleston, S. C. In September, 1869, and April 1870, and at various later dates, Mr. Holden obtained patents on his "regaled" ice making system.

In 1868, Charles Tellier, of Passy, near Paris, took out patents on his compression apparatus, whose refrigerating agent was methylic ether, and which was designed to make ice and to refrigerate air and liquids. The date of his letters patent in the United States was June 5, 1869, and one of his machines was erected in the Old Canal Brewery, New Orleans, by George Metz, with the object of producing cold, dry air, and making ale and lager beer without the use of ice.

In the seventies appeared the inventions of Francis D. Coppet of New Orleans; Franz Windhausen, Germany; Prof. C. P. G. Linde of Munich, Bavaria; Raoul P. Pictet, Geneva, Switzerland; Thos. L. Rankin of Ohio; Martin & Beath, San Francisco; A. T. Ballentine of Maine; James Boyle of Texas, and David Boyle of Chicago.

In 1877 Mr. Enright designed and built a machine having a vertical double-acting compressor, and in the fall of the year one of this type was installed in the brewery of A. Ziegele of Buffalo, N. Y. In 1878 patents were issued to the inventor, not only for his double-acting compressor, but for the pipe joint commonly known as the Arctic.

Vincent constructed a chloride of methyl compression machine in 1878. M. Raoul Pictet invented a sulphurous acid machine about 1875. This machine is used in France and Switzerland. Dr. Carl Linde, of Munich, introduced the ammonia machine in 1876.

In 1878, the first compression machine made by C. J. Ball was erected at Dallas, Tex. Upon his retirement he was succeeded by his son, P. D. C. Ball, who conducted the business under the name of the Ice & Cold Machine Co., until 1920, at which time the name of the company was changed to the Ball Ice Machine Co.

The first De La Vergne refrigerating machine was placed in the Hermann Brewery, New York City, in 1879. One of the inventors of the original apparatus, John C. De La Vergne, was engaged in the brewing industry in 1876, and in 1881 he formed the De La Vergne Refrigerating Machine Co., for the manufacture of the so-called De La Vergne-Mixer Machine, the second patentee being William M. Mixer of New York.

The refrigerating department of the Frick Co. originated about 1881, when either Mr. Jariman or Mr. Ferguson of Baltimore, Md., submitted plans of machinery to George Frick, and plants were subsequently erected for several parties in that city.

About 1882 Peter Weisel, the founder of the business now conducted by the Vilter Manufacturing Co., Milwaukee, Wis., designed a double-acting horizontal refrigerating machine which the firm of Weisel & Vilter commenced to build in that year. The first machine was installed in the Cream City Brewery, Milwaukee.

In 1885 W. G. Lock, an engineer of Sidney, Australia, patented a compound compressor for ammonia consisting of two single-acting high and low-pressure pumps, side by side. Patents covering the idea were issued as early as 1867, and the Lock improvements, together with the St. Clair compound machine, manufactured by the York Manufacturing Co., were great improvements on the originals. Thomas Shipley, vice-president and general manager of the company, made a number of most important changes and improvements on the originals, and also patented other improvements on ice making and refrigerating plants.

The compression refrigerating machine is now produced by a number of the leading manufacturers in the United States.

The carbonic acid machine was patented by Raydt in 1881 and later by Windhausen in 1886. This type machine is made by Messrs. J. and E. Hall of Dartford, Eng., The Linde Co., Messrs. Haslam and Hall and the Pulsometer Co.

The carbonic acid machine was introduced in the United States in the early eighties, and is now manufactured by American Carbonic Co., Brunswick-Kroeschell Co., Frick Co., Norwalk Iron Works, Wittenmeier Machinery Co., and others.

Vapor Compression Machines.—Most of the mechanical refrigeration of today is performed by vapor compression machines. In this process, a liquid is used which can be alternately liquefied and vaporized.

The liquids in common use are ammonia, sulphur dioxide, methyl chloride, ethyl chloride, ether, and carbon dioxide. The refrigerating cycle may be divided into four different phases:

1. Throttling effect through expansion valve.
2. Vaporization process in cooling coils.
3. Compression of vapor in compressor.
4. Cooling and condensing of vapor in condenser.

Refrigeration is produced by the latent heat of vaporization of these substances, all of which have a relatively low boiling point. The vapor resulting from the vaporization of the liquid in the cooling element is conducted to the suction side of the compressor. This vapor usually reaches the compressor in a slightly superheated condition. The compressor then forces the gas into the condensing element, where it is liquefied by cooling, usually by means of water or air. The liquid refrigerant is then allowed to return to the cooling element through an expansion valve or a restricted orifice. This cycle is continuous.

The restricted orifice must always be sealed on the condensing or high pressure side with liquid refrigerant, in order to function properly.

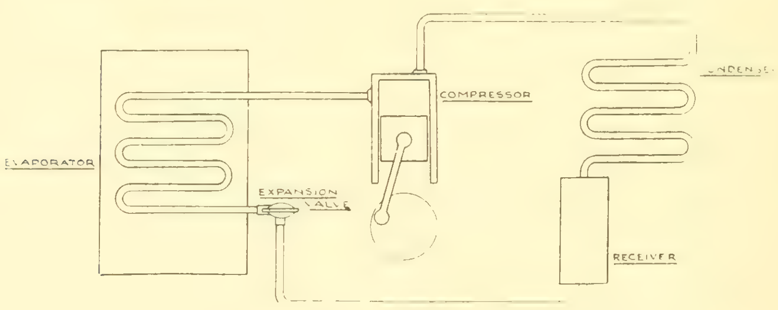


FIG. 9.—COMPRESSION REFRIGERATING SYSTEM.

The cooling element may operate either on a flooded or dry system. In the flooded system, a relatively large amount of the liquid is stored in the cooling element and a regulation of the restricted orifice keeps this amount nearly constant. In the dry system, the regulation of this orifice is usually controlled by the pressure of the low or evaporating side.

Statistics show that more than 90 per cent of all the refrigerating and ice making plants in the United States today are operated on the ammonia compression system. This is only true of the commercial or larger size plants as the household systems favor sulphur dioxide compression machines.

The compression refrigerating system is shown diagramatically by Fig. 9. The five essential parts shown are the compressor, condenser, receiver, expansion valve, and evaporator. An ordinary piston type of compressor is illustrated.

Chemical Methods.—It is a well known fact that when ice melts the temperature remains constantly at 32° F. Heat is supplied to cause this physical change of state from a solid to a liquid, and if the rate of heat supply be increased or decreased there will be no change in the temperature of the ice but simply a change in the rate of melting. Mixtures of some salts with ice and of certain salts with water or acids do not follow this same rule. For example, if salt is mixed with ice the rate of melting will tend to increase more rapidly than the heat is absorbed and the temperature will fall below that of melting ice. The temperature will be depressed a certain amount depending upon the per cent of salt used.

United States Department of Agriculture Bulletin No. 98 gives the temperature resulting from mixtures of ice and salt as follows:

Per Cent Salt	Degrees F.
0	32
5	27
10	20
15	11
20	1.5
25	—10.

The temperature of water may be lowered as much as 40° F. by dissolving ammonium nitrate in it. Ice may be formed in this way.

The lowering of temperature by means of ice and salt mixtures is shown graphically in Fig. 10. This figure illustrates how the temperature is reduced as the percentage of salt is increased. This chart is for ordinary salt, sodium chloride.

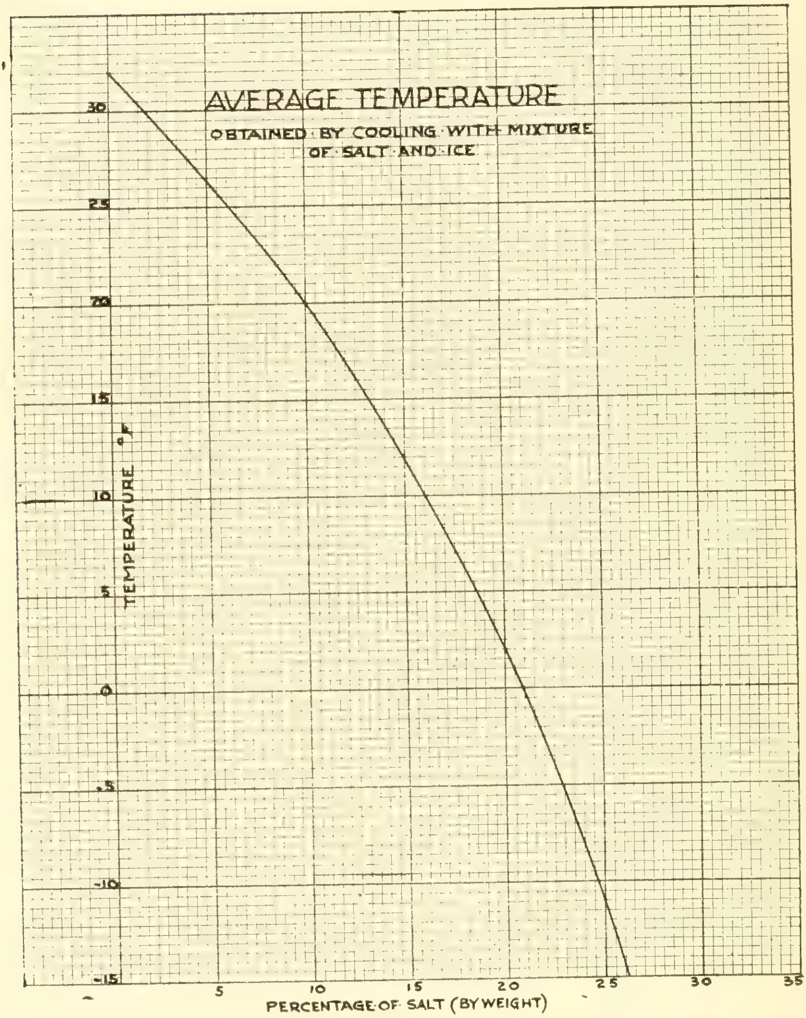


FIG. 10.—TEMPERATURES OBTAINED BY ICE AND SALT MIXTURES.

Water for Cooling Food.—Farmers' Bulletin No. 375 of the United States Department of Agriculture gives the following, in reference to cooling of foods, by means of water:

There are many ways of lowering temperature by utilizing the fact that water when evaporating draws off heat from surrounding objects. If a pitcher of water be wrapped with a cloth which is kept saturated and exposed to a draft of air, the temperatures of the water in the pitcher will be lowered by several degrees.

A receptacle in which food is placed may be cooled in the same way. Take a wooden box with a sound bottom made of one piece and invert it. Tack a layer of cotton batting over it and cover with some coarse cloth. It is now to be kept wet by some contrivance that will furnish an automatic drip. The writer used for this purpose an old aluminum pan which had in it a half dozen very tiny holes, and when filled with water it supplied just enough water to keep the cloth saturated. Under this box lettuce in cold water, a cold pudding, a pat of butter, and other food were placed and kept in good condition. A pan of milk lowered into another of cold water is kept from souring many hours longer than if it was unprotected from the surrounding air. Spring water of low temperature is used by many farmers' wives to keep milk and butter cool, and a "spring house" is a common thing on many farms, though less depended upon than was the case before ice houses, refrigerators and ice chests became so common.

It is also an old-fashioned practice to lower foods in covered pails into the well and suspend them not far above the surface of the water.

Requirements.—The requirements of a household refrigerating machine may be summarized as follows:

1. Maintain food compartments between 40—50° F .automatically.
2. Freeze water and desserts in reasonable length of time.
3. Low initial cost.
4. Dependable operation without adjustments, hand controls, or service.
5. Simplicity of design.
6. Simplicity of operation.
7. Efficiency of operation.
8. Quietness of operation.
9. Prevent leakage at stuffing box
10. Accessibility for repairs.
11. Safety of operation of exterior moving parts, of electrical apparatus or fuel burners.
12. Adaptability for installing as a single unit with cabinet.
13. Freedom from wear of moving parts.

14. Positive operation of valves.
15. Insure necessary lubrication under all conditions of service.
16. Prevent misplacement of lubricant.
17. Limit the number of gasket and pipe connections whereby refrigerating gas might escape.
18. Protect compressor from damage of pumping liquid refrigerant or lubricant.
19. Insure necessary cooling of compressor and motor.
20. Protect metals from rust and corrosion.

The household refrigerating machine has been under development for the past forty years. This work includes problems in mechanical, electrical, and chemical engineering. It has proven very difficult to construct a machine which will start and stop itself at required intervals, which will be self-regulating and self-oiling under all conditions, and which will be fool-proof and of such simplicity that a servant can operate it.

The machine should be entirely automatic as the advantages gained over the use of ice are not sufficient to compensate for a manually controlled system. Machines have been proposed which would be started manually and stopped automatically. Other plants have been proposed which would operate all of the time, varying the speed of the compressor according to the temperature in the food compartment. These experiments have not proven successful commercially.

The machines should make ice in small quantities or freeze desserts for table use. This feature assures the user that it is functioning properly. Experience shows that thermometers placed in food compartments are seldom understood, but the fact that ice is frozen and stored in the brine tank or cooling element is convincing proof that the machine is operating satisfactorily. The time required to freeze ices or desserts should not be longer than five hours, the usual time between meals, unless there is a large ice storing capacity insuring a reserve supply.

A large amount of work has been done on compressor design and development. It has been estimated that 90 per cent of the experimental work performed on household refrigerating machines has been on compressor development. Many concerns have met with financial difficulties before emerging

from the compressor development stage, while others have placed their machines on the market without taking time to develop the other important parts of the refrigerating system. Some very satisfactory compressors have been built and efforts are now being made to better the condensing, evaporating, ice making, and automatic control features.

In Europe and the tropics where labor is cheap and electricity is not available, there is a demand for hand operated machines. These are produced in large quantities, usually of a small refrigerating capacity, just sufficient to cool a carafe of water in a few minutes and make several pounds of ice in a half hour. The larger sizes will make 20 to 30 pounds of ice per hour. These are vacuum systems using sulphuric acid to absorb the water vapor, an improved form of the Carré sulphuric acid freezing machine.

Household refrigerating machines will not be used in large quantities until the mechanical features have been perfected, and until they operate at a cost comparable with that of buying ice. It is merely an improvement on existing conditions.

The initial cost must be low as the average family uses between 100 and 200 lbs. of ice weekly. The average yearly cost of ice would be about $40.00.

The Compressor.—The reciprocating type of compressor is in general use with refrigerants such as sulphur dioxide, ammonia, methyl chloride, carbon dioxide, and high pressure air.

Blowers and turbine compressors are mostly used with refrigerants such as ethyl chloride, ether, formic-aldehyde, and low pressure air. With these gases, a relatively large amount of gas must be handled.

Herringbone gear compressors have been used to some extent on sulphur dioxide machines, but they have not as yet met with success commercially.

Sulphur dioxide compressors are used most extensively on household refrigerating machines. These compressors are usually of the single-acting type with two vertical cylinders, although some machines on the market today have one and

others three vertical single-acting cylinders. They operate at from 250 to 500 r.p.m., the speed being limited mostly by noise and efficiency of the valves. The multi-cylinder compressors are favored in order to reduce the starting torque.

Some progress has been made with sulphur dioxide compressors operating at motor speed or about 1750 r.p.m. The cylinder on a machine of this type is usually less than one inch in diameter, for use with a ¼-hp. motor. Most machines using these compressors have been of the double-acting single cylinder design. One manufacturer uses a four-cylinder compressor operating at motor speed.

The displacement in cu. in. per min. for a compressor of average efficiency necessary to produce the refrigerating effect equivalent to 100 lbs. of ice melting per day is approximately as follows:

Ethyl chloride	3,450 to 5,100
Sulphur dioxide	1,200 to 1,800
Ammonia	450 to 670
Carbon dioxide	90 to 130
Methyl chloride	900 to 1,340

An important part of the compressor design is the packing gland which seals the drive shaft. Most of the first models used a packing of fiber, asbestos, and graphite, forced against the shaft by means of a spring acting against a metal gland. The spring automatically compensates for wear. It is advantageous to have oil on both sides of a packing gland of this type.

A later development is to use a ring of metal containing graphite. This ring is forced by means of a spring against a collar turned on the shaft. This ring may be attached to one end of a metal bellows, thus having only one surface to seal instead of two if the metal bellows is not used.

It is a decided advantage to have the packing gland on the slower speed shaft when a reduced speed drive is used. Some machines are entirely or partly enclosed, thus eliminating the packing gland.

The design of a compressor includes a system of lubrication which should function under many different operating conditions. The lubricant usually has a tendency to locate

and stay in the evaporating coils. This condition lowers the rate of heat transmission in the evaporator. The return of lubricant to the compressor through the suction line is usually the result of some temporary unusual working condition. It is difficult to design a refrigerating system in which the lubricant returns regularly from the evaporation element to the compressor.

The piston type compressor usually has surplus lubrication of the pistons and cylinders.

In the herringbone gear type compressor, it is necessary to have generous lubrication of the gears in order to pump gas. Small holes feed lubricant to the gears during part of their rotation. If too much lubricant is supplied it decreases the amount of gas pumped. Lubrication is one of the most difficult problems in the gear type compressor.

The rotary compressor presents a difficult lubricating problem as the blades usually wear rapidly when forced against a surface.

TABLE XLIX.—AIR PUMPING TEST ON A STANDARD TWO-CYLINDER AIR-COOLED SULPHUR DIOXIDE COMPRESSOR.

Discharge Pressure Pounds Gauge	Volumetric Efficiency Percent	Watt-minutes per cu. ft. Free Air Delivered per Minute
0	72.5	253
20	65.8	330
40	58.7	402
60	52.1	481
80	45.1	573

Using ¼-hp., 110-volt, a. c. R. I. Standard Motor.

Table XLIX gives the results of an air pumping test on a standard two-cylinder air-cooled sulphur dioxide compressor. The test results give the volumetric efficiencies as the discharge pressure is increased from 0 to 80 pounds per square inch gauge. The resulting watt-minutes per cubic foot of free air delivered per minute are given also.

Table L gives similar results for an air pumping test on a standard three-cylinder air-cooled sulphur dioxide compressor.

TABLE L.—AIR PUMPING TEST ON A STANDARD THREE-CYLINDER AIR-COOLED SULPHUR DIOXIDE COMPRESSOR.

Discharge Pressure Pounds Gauge	Volumetric Efficiency Percent	Watt-minutes per cu. ft. Free Air Delivered per Minute
0	70.8	238
20	61.3	342
40	56.6	432
60	52.5	526
80	49.7	620

Using 1/6-hp., 110-volt, a. c. R. I. Motor.

Table LI gives similar results for an air-pumped test on a herringbone-geared type compressor.

TABLE LI.—AIR PUMPING TEST ON HERRINGBONE GEAR TYPE COMPRESSOR.

Discharge Pressure Pounds Gauge	Cu. Ft. Free Air Delivered Per Minute	Watt-minutes per cu. ft. Free Air Delivered per Min.
0	0.87	150
10	0.857	187
20	0.833	240
30	0.78	302
40	0.75	367
50	0.75	413
60	0.74	440
70	0.732	512
80	0.69	610

Used ¼-hp., 110-volt a. c. R. I. Standard Motor (1,775 r.p.m.).

The Condenser.—The condenser is used to cool and liquefy the refrigerant gas as it leaves the compressor or blower. The customary cooling medium is either water or air.

Some systems use tap water from the city mains. A sufficient quantity of water should be used so that its outlet temperature is not more than 15° or 20° F. higher than the inlet or tap water temperature. If less water is used, an excessive condensing pressure will likely result. On large plants it is customary to use sufficient water for a 10° F. water inlet and outlet differential.

Some household systems use the same water over and over again. In a system of this kind, it is an advantage to conduct the warm water leaving the condenser to a well or

tank which is in the ground. In this way the water is cooled during the periods when the machine is not in operation.

The water supply is sometimes regulated by a valve which opens automatically at a certain predetermined condensing pressure. Then as the condensing pressure increases, the valve opens wider allowing more water to flow through the condensing coil. This system compensates for different temperatures and pressure of condensing water and to some extent, for other variations in operating conditions. A machine operating on this principle requires still another control to prevent operation when water is not available, even though this water-regulating valve functions properly.

Another water control system in use is a valve which opens automatically when the machine is operating and closes during the inoperative periods. This valve does not regulate the amount of water used so that any change in pressure or temperature of the water supply is not compensated for automatically. This system may waste considerable water or may cause the plant to operate inefficiently at times.

The packing on automatic regulating water valves has given some trouble in service. This difficulty has been met by using a copper bellows or rubber diaphragm to seal the valve stem and eliminate the packing troubles.

There are three general types of water-cooled condensers in use: The submerged type, in which the pipe containing the refrigerant gas is submerged in the water, and the double-pipe condenser in which one pipe is inside a larger one. The refrigerant gas flows through the annular space and the water through the inside pipe. This gives the advantage of some cooling by the atmosphere. A condenser of this type is usually arranged to have counter-current heat flow, the cold water entering the liquid outlet at the end of the condenser. The other method is to submerge the cooling water pipe in the gas space itself. The refrigerant gas condenses on the pipe and drops into a sump or receiver.

When copper tubing is used for water-cooled condensers, the usual practice is to use from two to three square feet of cooling surface per 100 lbs. ice melting effect.

On a small household plant, the average cost of water is less than two per cent of the total operating cost, so that it is usually practical to use tap water which wastes to the drain.

Air-cooled condensers are rapidly gaining favor for small household machines. Some of the more important advantages of the air-cooled condenser are: Lower initial cost, reduced cost of installation, simplified apparatus, no danger of water lines freezing in winter, and water cooling limits location of mechanical unit.

Air-cooled machines usually operate at condensing pressures, twenty-five to thirty per cent higher than on water-cooled systems. This of course lowers the efficiency of the system, however the increased simplicity may compensate for this loss in efficiency.

There are two systems of air cooling in common use. In the dead air system a relatively large amount of condenser cooling surface is used. With the forced air system a smaller amount of condenser surface is used. A fan or blower forces the air over all or part of the condenser, thus procuring more efficient use of the cooling surface and permitting the use of less surface.

Machines using the dead air type condenser have been used mostly on installations where the mechanical unit is placed in the cellar. This assures a relatively low condenser temperature, averaging between 7° and 10° F. lower than the refrigerating cabinet environment temperature.

The usual practice on dead air-cooled condensers is to use from ten to twelve square feet condenser surface for each one hundred pounds ice melting refrigerating capacity. Less than half this surface is needed with forced air cooling, the exact amount depending upon the amount of air used and the efficiency with which it is used.

Some air-cooled systems use a large capacity condenser so that it also serves as a receiver for the liquid refrigerant. This feature eliminates pipe connections and adds to the simplicity of the machine.

Table LII gives capacities and horsepower for different sizes of Sirocco blowers. This table gives the cubic feet of air delivered per minute r.p.m. and brake hp., at various suction

pressures, expressed in inches of water for some of the small blowers.

TABLE LII. — SIROCCO BLOWER DATA, CAPACITIES AND HORSE POWER.

Number of Fan	Diameter of Wheel, Inches	Suction Pressure Inches of Water	Cubic Feet Air Delivered per Minute	R. P. M.	Brake Horse Power
00	3	¼	40	2220	0.004
00	3	½	57	3160	0.0115
00	3	¾	69	3885	0.0208
0	4½	¼	90	1480	0.0087
0	4½	½	127	2110	0.0258
0	4½	¾	155	2590	0.0466
0	4½	1	182	3025	0.0745
0	4½	1½	222	3700	0.137
1	6	¼	160	1110	0.0155
1	6	½	226	1580	0.046
1	6	¾	276	1940	0.083
1	6	1	325	2270	0.1325
1	6	1½	394	2770	0.244
1	6	2	464	3240	0.381
1¼	7½	¼	250	885	0.0242
1¼	7½	½	354	1265	0.072
1¼	7½	¾	431	1555	0.1295
1¼	7½	1	507	1813	0.207
1¼	7½	1½	616	2220	0.381
1¼	7½	2	725	2585	0.595

The following are some of the leading characteristics of fans:

Capacity varies as speed
Pressure varies as $(\text{speed})^2$
Horsepower varies as $(\text{speed})^3$
Horsepower varies as $(\text{capacity})^3$
Horsepower varies as $(\text{pressure})^{3/2}$
Horsepower varies as $(\text{diameter})^2$
Speed varies inversely as diameter.
Speed varies as density.
Capacity varies as $\sqrt{\text{absolute temperature}}$.
Horsepower varies as $\sqrt{\text{absolute temperature}}$.

Table LIII gives the results of some tests of exhaust fans. In this table, it will be observed that the size of the fan varies from three inches to sixteen inches, and the corresponding data are given for r.p.m, watts consumed, air velocity in feet per minute, air delivered in cubic feet per minute, cubic feet delivered per watt of electrical energy consumed, and characteristic of electric current.

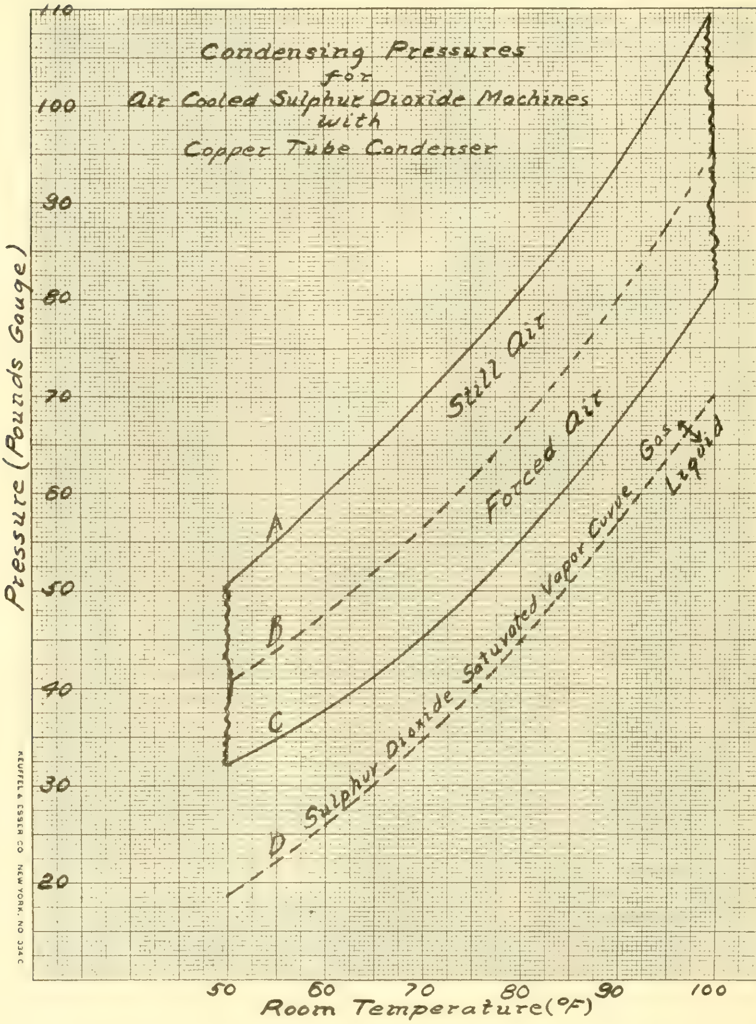


FIG. 11.—CONDENSING PRESSURE FOR AIR-COOLED SULPHUR DIOXIDE MACHINE.

TABLE LIII.—TESTS ON EXHAUST FANS.

Diameter Fan	Discharge Outlet	R.P.M.	Watts	Air Velocity per Minute	Air Delivered Cu. Ft. per Minute	Cu. Ft. per Watt	110 Volt
3 in.	2½ in.	2660	37	2355	80.1	2.16	D.C.
3 in.	2½ in.	2075	29	1775	80.3	2.08	D.C.
4½ in.	3⅝ in.	1730	66	1780	125	1.89	A.C.
6 in.	4⁴⁄₁₀ in.	1100	111	1680	201	1.82	A.C.
9 in.	9 in.	1610	38	815	360	9.48	D.C.
9 in.	9 in.	1550	66	1185	523	7.93	A.C.
12 in.	12 in.	1140	58	818	643	11.08	D.C.
12 in.	12 in.	1620	48	520	489	10.18	A.C.
12 in.	12 in.	1400	67	1170	921	13.7	A.C.
16 in.	16 in.	1030	81.5	518	805	9.88	A.C.

Condensing Pressure for Air Cooled Compressors. — Fig. 11 shows the condensing pressure in pounds per square inch gauge for air-cooled sulphur dioxide refrigerating machines, equipped with copper tube condensers. The curves show graphically how the condensing pressure increases with the increase of the room temperature. The space between curves A and B shows the result when the proper tube condensers are exposed to still air, while the space between curves B and C shows the results when forced air circulation over the condenser is used. The curve D is the saturated vapor curve for sulphur dioxide and represents the corresponding condensing temperatures for the pressures shown on the left-hand side of the diagram. The relative distances between curve D and the curves A, B, and C show how nearly the condenser pressure approaches the theoretical possibilities.

Flintlock Condensers.—Fig. 12 shows a new type condenser developed for air-cooled electric refrigerators by Flintlock Corporation of Detroit, Michigan.

One lineal foot of this finned tubing has been found to have the equivalent cooling capacity of ten feet of copper tubing of equal size, when air is drawn through at an average velocity of 500 feet per minute.

Tests have proven that draw fans are more efficient than blow fans. Only that amount of air which can be drawn through the free area of the condenser need be handled by the fan.

Fig. 13 shows a cross section of tubes also the internal fins. The construction is of brass tinned inside and out. The

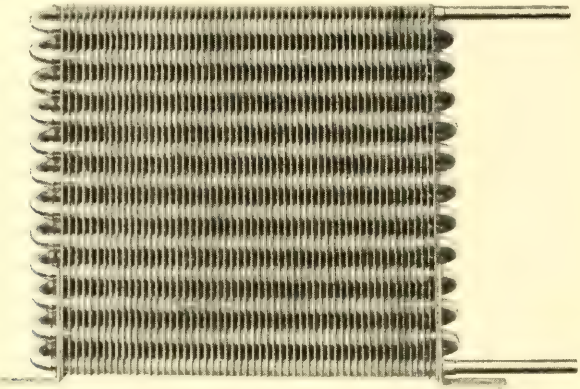


FIG. 12—FLINTLOCK AIR COOLED CONDENSER.

tubes are an integral part of the fins. Heat transmission does not pass through a soldered joint.

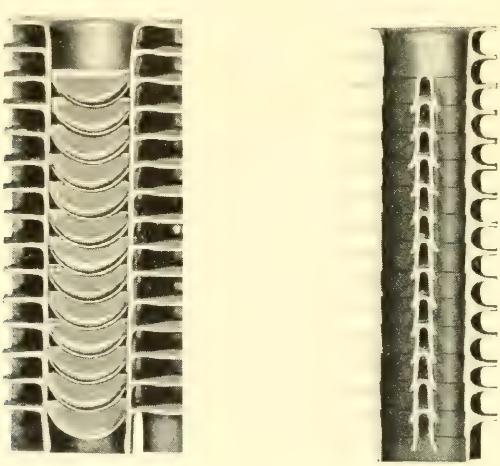


FIG. 13. CROSS SECTION OF TUBES SHOWING INTERAL FINS.

Fig. 14 is a typical installation of this type condenser on a compressor unit.

Tubes and Spiral Fin Tubes.—The use of drawn seamless tubes or coils made into simple, or sometimes fairly compli-

cated forms, is very extensive throughout the refrigerating industry. Considering household machines, the conventional condenser and evaporator consists of many feet of seamless copper tubes, or steel tubes in case ammonia is used as the refrigerant. The copper tubes used ordinarily are 1/4 inch outside diameter, 5/16 inch up to 1/2 inch outside diameter with a wall thickness of about 0.015 to 0.032 inch. These tubes

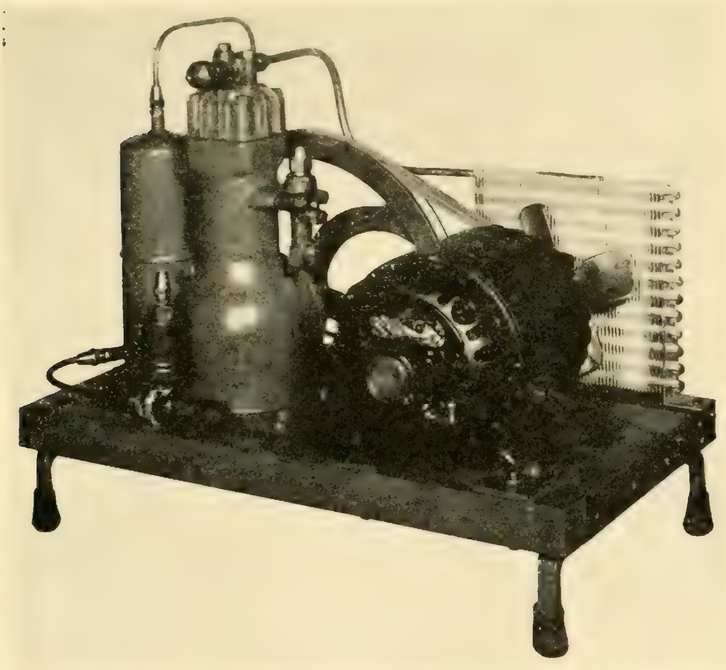


FIG. 14.—TYPICAL INSTALLATION OF FLINTLOCK CONDENSER.

have ample bursting strength, are soft, easy to work with and when formed into coils present an attractive appearance.

In some designs the tubing is flattened before or while it is being formed into a coil; the object in flatting the tubes is, of course, for a given tube spacing to increase the area of the air passages between the tubes. For example, if a coil is formed with 3/8 inch tubes the center lines of which are 5/8 inch apart, the air passage between the tubes will be 2/8 or

1/4 inch. However, if the same tubes are flattened to a thickness of 3/16 inch the air passage will be increased from 1/4 inch to 7/16 inch. Further, if desired, the tubes can be placed closer together so that the air passage is still 1/4 inch as before, but the overall dimensions of the coil, consisting of a

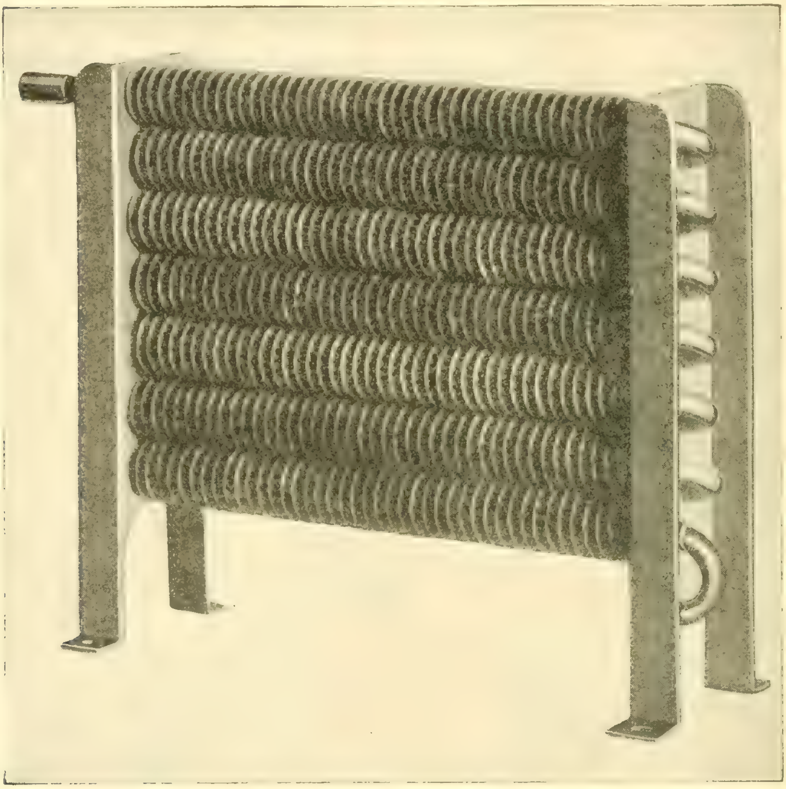


FIG. 15.—SPIRAL FIN TUBE CONDENSER.

given number of feet of tubing, will obviously be reduced. In any case it is clear that there is a definite gain in the use of flat tubes and whether or not this gain is sufficient to warrant the expense of flattening the tubes should be decided in each case.

Instead of using plain tubing for condensers, evaporators, etc., it is possible and very advisable under certain conditions

to use so-called spiral fin tubes. As the name indicates, a spiral fin, about 1/4 inch wide and 0.006 to 0.008 inches thick, is wound spirally around the tube and attached to it securely

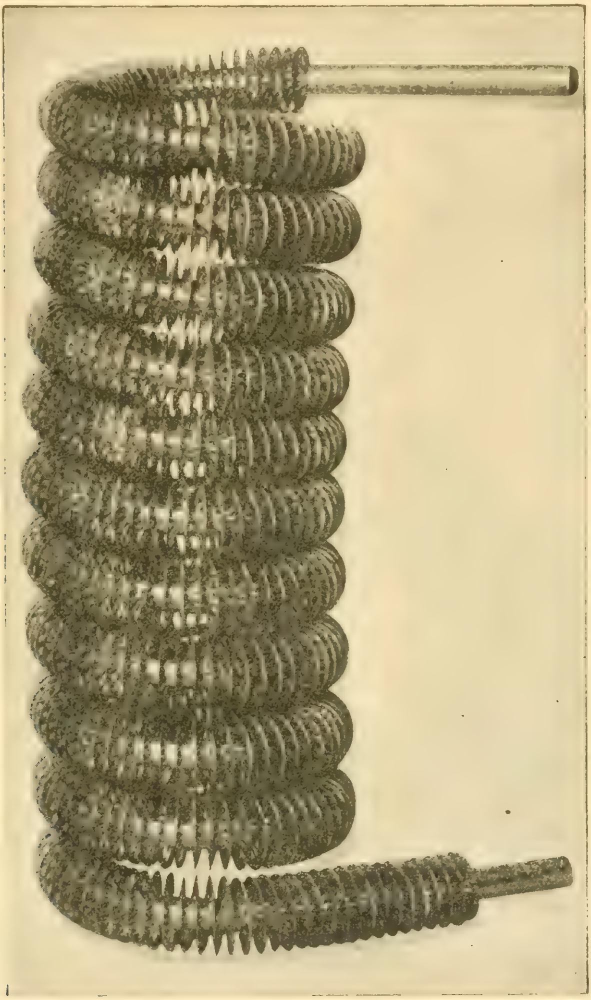


FIG. 16.—SHOWING HOW SPIRAL FIN TUBE CAN BE SHAPED.

by means of solder. The finished product is known as a spiral fin tube. Such a tube can be wound and formed into various shapes as shown in Figs. 15, 16 and 17 showing typical con-

densers made by the McCord Radiator Company of Detroit, Mich.

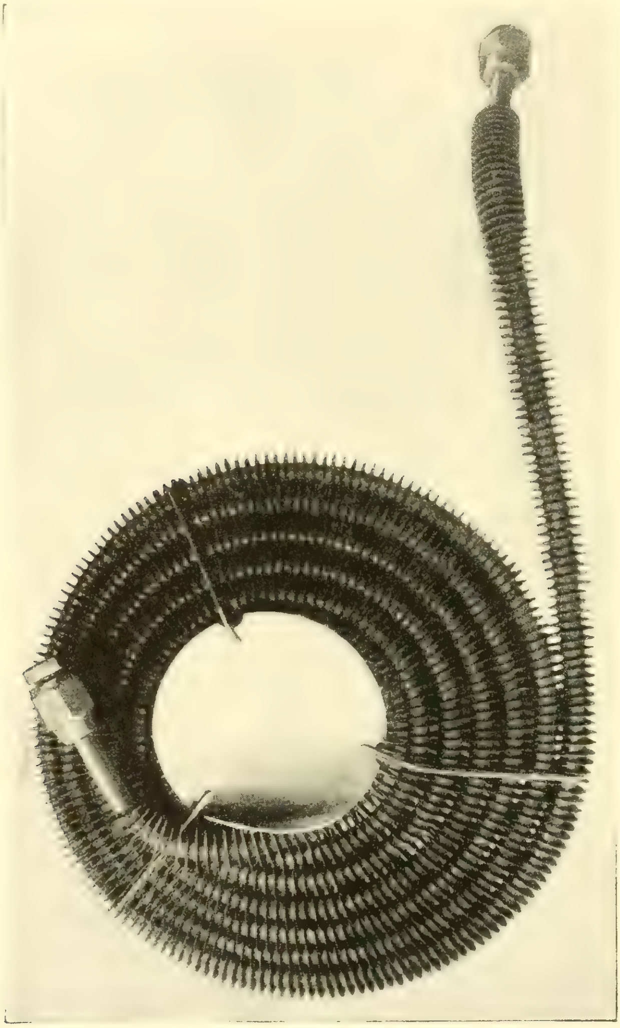


FIG. 17.—SPIRAL FIN TUBE.

A glance at Table LIV will show that the total outside surface of the spiral fin tubes is nearly seven times as large as the surface of the plain tubes from which they are made.

Since heat transfer from metal to a fluid such as air or brine depends upon the surface, it is clear that the spiral fin tube should have some advantage over the plain tube. This advantage is particularly large in such cases as that of condensing a refrigerant inside of a tube, over which a blast of air is directed by means of a fan or a blower. In a case of this kind the heat absorbed by the air per square foot of tube surface is very small compared to the heat transferred by the refrigerant to the tube. For example, if the latter is 20 times as large as the former it is clear that the factor limiting the overall heat transfer is the rate at which heat is absorbed by the air. However, suppose we increase the surface exposed to the air, while the surface in contact with the refrigerant is maintained the same; then one square foot of the inner surface of the tube will furnish heat to seven square feet of the outer surface of the tube, instead of one square foot of the outer surface, and conditions will evidently be greatly improved.

TABLE LIV—STANDARD SIZES OF FLINTLOCK CONDENSERS

Size	Width	No. Tubes	I. D. Tubes	No. Fins	Square Inch Radiating Surface
6" x 6"	1¼"	18	11/32"	43	609
7" x 7"	1¼"	20	11/32"	50	814
8" x 8"	1¼"	24	11/32"	57	1114
9" x 9"	1¼"	26	11/32"	64	1364
10" x 10"	1¼"	30	11/32"	71	1682
10" x 12"	1¼"	36	11/32"	71	2016
12" x 12"	1¼"	36	11/32"	85	2415
14" x 14"	1½"	32	7/16"	99	3778
16" x 18"	1½"	36	7/16"	113	4937

The heat transfer from the condensing refrigerant to the tube can very aptly be compared to a boulevard 140 feet wide, terminating at a large square which would correspond to the tube which has a high conductivity; if this square connects only with one pavement, say 20 or 30 feet wide, we shall have the case of the plain tube, but if we have seven such streets radiating from the square, we shall have the case of a spiral fin tube.

If the temeperature of the fin surface were the same as the temperature of the tube surface then a square foot of the fin surface would be equivalent to a square foot of the tube surface. But this is not the case, and therefore, a spiral fin tube having one square foot of tube surface and six square feet of fin surface will have an effective heat transfer capacity of $1 + (0.60 \times 6) = (1 + 3.6)\ 4.6$ instead of a capacity of $(1 + 6) = 7$, assuming that the efficiency of the fin surface is 60 per cent of that of the tube, while the plain tube would have a heat transfer capacity of one.

Another advantage of the spiral fin tube is the adaptability to compact designs. If 30 feet of spiral fin tubing replace 120 feet of plain tubing, as it has been done in practice, then it is clear that there will result compactness of design, and economy of space.

Further this compactness of design makes possible the improvement and control of the air flow through the coils. A very good example of this is Fig. 18 where the round condenser can be made to cover the fan and thus use its air blast very efficiently.

Calculation of the Surface of a Spiral Fin Tube.—Consider a 3/8 inch outside diameter tube wound spirally with a fin 1/4 inch wide and 1/6 inch pitch. The surface per foot length will be:

$\pi 3/8 \times 12 = 14.18$ square inches per foot length of tube. Suppose that in winding the ribbon around the tube the outside diameter is maintained at $(1/4 + 3/8 + 1/4) = 7/8$ inch, and the excess material next to the tube is crimped. Then, the length of the ribbon, per turn will be practically, $\pi\ (7/8)$ and its area, facing upward, $\pi\ (7/8)\ (1/4)$. Thus the total fin or indirect surface, as it is sometimes called will be:

$\pi\ 7/8 \times 1/4 \times 2 \times 6 \times 12 = 99$ square inches per foot length of tube. Where the factor 2 is introduced because there are two surfaces, one facing upward and the other facing downward; the factor 6 is used because we have 6 turns per inch length of tube and 12 in order to get the surface per foot

length of tube. Adding the direct and indirect or fin surface we have

$$14.18 + 99 = 113.18 \text{ square inches per foot length.}$$
$$= 0.785 \text{ square feet per foot length.}$$

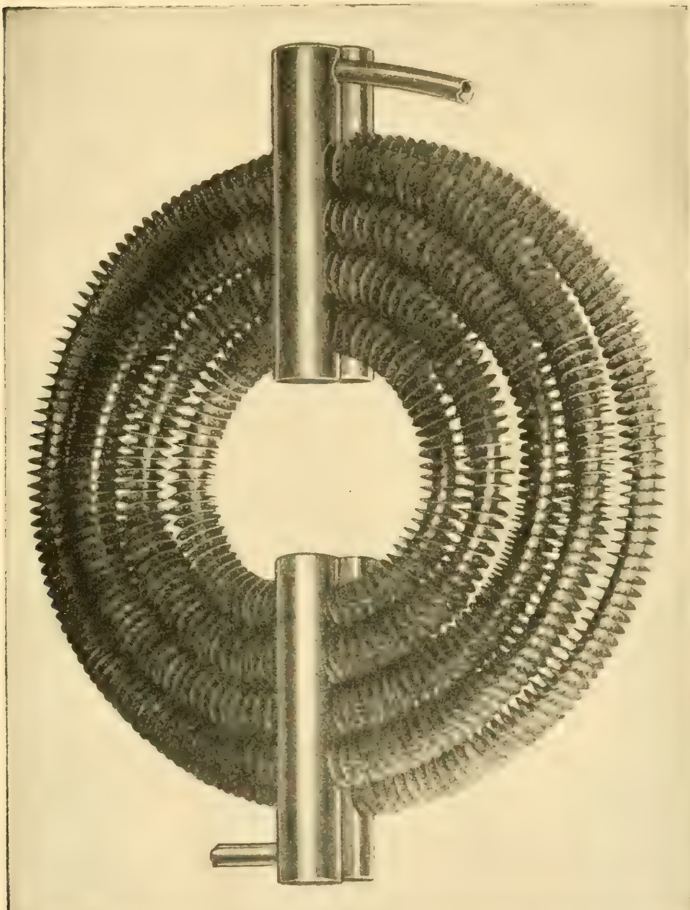


FIG. 18.—ROUND CONDENSER, DESIGNED TO COVER THE FAN.

Next suppose that instead of crimping the fin on the inside, we draw it through a die, and force it to assume a flat ring-like shape around the tube. The surface of the ring will be

$$\pi\,(7/8)^2\,(1/4) - \pi\,(3/8)^2\,(1/4) \text{ or}$$
$$\text{Approximately } \pi\,(5/8)\,(1/4)$$

Where 5/8 is the average diameter of the ring and 1/4 its width. Thus the total indirect surface will be

$\pi\ 5/8 \times 1/4 \times 2 \times 6 \times 12 = 70.7$ square inches per foot length.

The total surface of the spiral fin tube will be $70.7 + 14.18 = 84.88$ square inches per foot length. Thus the total surface

TABLE LV—DATA ON COMMERCIAL FIN TUBES

	Tube Sizes				
	5/16	3/8	7/16	1/2	5/8
Outside Diameter of Tubes, inches	0.312	0.375	0.437	0.500	0.625
Outside surface of tubes, square inches per foot length	11.78	14.18	16.49	18.85	23.56
Fins per inch length of tube	6	6	6	6	6
Width of fins, inches	0.187	0.250	0.250	0.250	0.250
Outside surface of fins when crimped, square inches per foot length	58.31	99.0	106.0	113.1	127.2
Total outside surface (crimped fins), square inches per foot length	70.09	113.18	122.49	131.95	150.76
Square feet per foot length	4.85	7.87	8.50	9.15	10.46
Outside surface of fins when not crimped, square inches per foot length	42.3	70.7	77.7	85	99
Total outside surface (fins not crimped), square inches per foot length	54.08	84.98	94.19	103.85	122.56
Square feet per foot length	3.76	5.9	6.54	7.21	8.72

of the crimped spiral fin tube is 113.2 square inches per foot length of tube, while that of the uncrimped spiral fin tube is 84.9 square inches or 75 per cent of the former.

Table LV gives in detail data on commercial spiral fin tubes, which were calculated as those outlined above.

The Evaporator.—There are two types of evaporator or cooling elements in general use. The type operating with an expansion valve is sometimes called the "dry" system. The

other type, in which a relatively larger amount of liquid refrigerant is retained in the evaporator, is the "flooded" system.

The "flooded" system has several important advantages. Heat transfer is more rapid through surfaces contacting with liquid than through surfaces contacting with a gas or a mixture of a gas and a liquid. The additional liquid refrigerant in the evaporator has a certain heat storage capacity which may prove advantageous.

A direct expansion system for a household machine usually requires a much smaller quantity of refrigerant. This is an advantage, if any danger is involved should the gas escape in the home. The direct expansion system has an advantage in giving an easier starting load when the machine is first placed in operation. This condition is very important when an air-cooled condenser is used. This system usually operates with a more uniform suction pressure, thus automatically regulating the refrigerating load more closely than with the flooded system.

It is customary to control the supply of liquid refrigerant to the flooded system by a float valve. A float on the liquid refrigerant surface drops when the liquid refrigerant is vaporized and removed by the compressor. This opens a valve, allowing sufficient liquid to enter the evaporator to maintain the liquid level required by the float to close the valve.

This valve may be placed in a reservoir forming part of the flooded evaporator, or in the liquid sump or reservoir below the condenser. When the valve is placed outside of the refrigerator, it is necessary to insulate the liquid line to the evaporator. In order to avoid this insulated line, most designs show this valve located in a header forming part of the cooling unit.

An evaporator in common use consists of pipes or tubes immersed in a solution of calcium or salt brine contained in a sheet-metal tank. This tank is placed in the ice compartment of a refrigerator and usually functions at a surface temperature colder than ice.

The average brine temperature found to be suitable for household refrigerators is about 20° F. The temperature may vary as much as 10° above or below this amount during the

operating period without any objectionable results in operation. It has been found that with a 20° F. average brine temperature, ice and desserts can be frozen in quantities sufficient for household use within the shortest time intervals between meals, that is, five or six hours.

Experience has indicated that the food compartment of the average ice refrigerator will accommodate a large enough brine tank for the cooling with a 20° brine tank surface.

There are three principal factors involved in determining the amount of cooling performed by the evaporator:

1. Amount of effective evaporator surface.
2. Temperature of evaporator surface.
3. Rate of air circulation in the cabinet.

A brine tank will usually maintain a food compartment temperature under 50° F. under usual service conditions. If the brine tank has a surface equivalent to the average ice surface, it should, of course, produce lower food compartment temperatures, as the 20° F. brine tank surface is 12° colder than ice.

Some manufacturers use an evaporator made of pipes or tubing directly exposed to the air. This system eliminates the brine. Much difficulty has been experienced in making tanks to hold the brine solution, as there is a chemical and electrolytic action which frequently causes tanks to leak. This effect is especially bad with copper and solder exposed to the action of calcium chloride brine.

The brineless evaporator usually has a smaller heat storage capacity. However, with an automatic machine, this is not considered so important, as frequent operation is not objectionable. Sometimes this heat storage condition is improved by the addition of a heavy cast-iron sleeve to contain the ice trays and to also serve as a heat storage element.

A large amount of refrigerant is stored in the evaporator by some manufacturers to function as a heat storage capacity. When the heat storage capacity of the evaporator is relatively low, the cycles of operation are usually lengthened by increasing the temperature differential of the evaporating unit. A brine system might operate with a brine differential temperature of 4° (22°—18°). Nearly the same results would

be obtained on a brineless evaporator, say of half the heat storage capacity, but with a temperature differential of 8° (24°—16°). There would be some loss in efficiency in the latter case, as the compressor operates at lower efficiency at the lower suction pressure required to cool to 16° F. rather than 18° F.

It is very important to properly place the evaporator in the ice compartment. It should not project above or block the warm air flues. The warm air entering these flues should pass over the top of the evaporator with little or no restriction, so that it can drop along the four sides of the brine tank to replace the cold air passing out of the compartment. The sides of the evaporator should clear all side walls by at least two and, preferably, three inches. The clearance at the bottom should be at least three inches and preferably more.

The frost collecting on the evaporator sometimes interferes with the normal operating of the refrigerating system. As the evaporating surface is usually below 32°, moisture from the circulating air is deposited and freezes to the cold surfaces of the evaporator. This frost will gradually build up unless the evaporating surface temperature reaches 32° F. during the inoperative period of the cycle. This layer of frost acts as a heat insulator and increases the temperature in the food compartments. It is customary to stop the mechanical unit for certain periods every few weeks to permit this frost to melt off the evaporating surface.

It is an advantage to have an evaporator which will function so that the surface will have a high enough temperature to defrost each inoperative period of the refrigerating cycle. Some of the most important advantages are:

1. Eliminates food odors from cabinet.
2. Cooling element operates more efficiently.
3. Cooling effect more uniform.

The water vapor in the circulating air absorbs large quantities of gases and odors from the foods. Some of this water vapor is constantly being condensed on the surface of the cooling element. It is preferable to discharge this water to the drain as soon as possible. Freezing the water liberates a large per cent of the gases. Therefore the circulating air

will be greatly benefited if the condensed water vapor is discharged to the drain each inoperative period.

	B.t.u. per pound water vapor
1. To cool water vapor (50° to 32°)	18
2. To condense water vapor	970
3. To freeze water vapor	144
4. To cool ice or frost (32°—20°)	6
Total	1,138

It requires a relatively large quantity of heat to condense, freeze, and cool the water vapor deposited on the evaporator surface, as shown in the table on the preceding page.

The heat loss under Items 1 and 2 are necessary in order to have a dry food compartment with a relative humidity of approximately 60 to 80 per cent.

The heat loss under Items 3 and 4 could be saved by operating the evaporator at a surface temperature so that it will automatically defrost during the inoperative part of the cycle.

The efficiency of the evaporator surface for cooling the circulating air gradually decreases as the thickness of the layer of frost on it increases. The ice acts as a heat insulator. It is estimated that a layer of frost ½ inch in thickness will decrease the effectiveness of the cooling surface about twenty per cent.

Much difficulty has been experienced in returning lubricant from the evaporator to the compressor. In the usual household system there is a tendency for the lubricant to enter the evaporator, while if no special method is used for its return to the compressor it may collect in excessive quantities in the evaporator. An excessive amount of lubricant in the evaporator will reduce its heat-absorbing efficiency. Some household plants have a special oil return system, while others use oil traps to prevent this condition. It is an advantage to have the evaporator located above the compressor so that any oil in the suction line will drain to the compressor.

The rate of heat transmission between the coil and the brine in a direct expansion type of brine tank is from ten to fifteen B.t.u. per square foot per degree F. per hour. In a

flooded type tank the rate of heat transfer is about double this amount.

When direct expansion coils are used to cool unagitated air the rate of heat transmission is 1½ to 2 B.t.u. per square foot per degree F. per hour. With brine pipes the rate is 2 to 2½ B.t.u.

In designing an evaporator it is of importance to note the relative thermal conductivity of the following materials:

Corkboard	=	1.
Half inch air space	=	1.54
One inch air space	=	1.56
Water	=	13.
Brine (calcium or sodium)	=	15.
Ice	=	54.
Iron	=	1400.
Copper	=	8600.

Brine Tank Data.—Table LVI gives the properties of solution of calcium chloride in water. The gravity expressed in degrees Beaumé and in degrees salometer, per cent of calcium chloride, freezing point in degrees F., and the corresponding ammonia gauge pressure in pounds per square inch (corresponding to the freezing point) are given.

Table LVII gives data on the properties of solutions of common salt (sodium chloride) in water.

Table LVIII gives interesting brine tank data, relative to the heat-storing capacity and cost of various materials, which might be used to replace calcium chloride or sodium chloride brine. Specific gravity, specific heat, B.t.u. heat-storing capacity per pound of material in cents, and B.t.u. stored for each cent cost of material are given for some common substances, such as calcium and salt brine, water, cast iron, lead, copper, aluminum, concrete, sandstone, paraffin, oil, and kerosene. In reference to the heat stored per pound of material, it will be noted that water has the highest value. This is, of course, due to the high specific heat. Oil and kerosene are lowest, with approximately 0.4 B.t.u. per pound of material. In reference to the cost of material, it will be observed that the sandstone has the smallest cost, with sodium and calcium chloride brine next, and with aluminum as the highest cost. In reference to the B.t.u. stored for each cent cost of materials,

it will be noted that lead has the lowest value, this being 0.006, and that sandstone is the highest, with the value of 4.4 B.t.u.

TABLE LVI.—PROPERTIES OF SOLUTION OF CALCIUM CHLORIDE IN WATER

Specific Gravity at 60°F.	Per Cent Pure Calcium Chloride	Freezing Temp. Degree F.	Lbs. of Calcium Chloride Crystals (73 to 75%) in one Gal. of Brine	Weight, lbs. per Gal. at 60°F.
1.000	0.00	32.00	....	8.33
1.010	1.40	31.50	....	8.44
1.020	2.30	30.50	....	8.50
1.030	3.80	29.50	....	8.59
1.040	5.00	27.50	....	8.67
1.050	6.20	26.00	....	8.76
1.060	7.20	24.75	....	8.84
1.070	8.20	23.75	....	8.92
1.080	9.60	22.50	....	9.00
1.090	10.60	21.00	....	9.10
1.100	11.80	18.50	1.43	9.18
1.110	12.80	16.50	1.60	9.25
1.120	13.80	14.50	1.75	9.34
1.130	15.00	12.00	1.88	9.42
1.140	16.00	10.30	2.05	9.49
1.150	17.20	+ 7.52	2.18	9.58
1.160	18.30	+ 3.75	2.35	9.67
1.170	19.20	+ 1.50	2.50	9.77
1.175	19.85	− 1.50	2.56	9.80
1.180	20.20	− 2.50	2.65	9.85
1.190	21.20	− 5.50	2.80	9.93
1.200	22.20	− 9.50	2.95	10.00
1.210	23.20	−14.00	3.10	10.09
1.220	24.20	−18.00	3.30	10.16
1.230	25.10	−23.50	3.45	10.22
1.240	26.00	−27.04	3.60	10.34
1.250	27.00	−32.62	3.76	10.42
1.260	27.85	−39.00	4.00	10.52
1.270	28.80	−44.50	4.10	10.60
1.280	29.70	−52.50	4.35	10.68
1.290	30.60	−54.40	4.50	10.76
1.300	31.60	−42.50	4.70	10.84
1.310	32.40	−32.50	4.90	10.92
1.320	33.40	−17.00	5.10	11.00
1.330	34.20	− 4.00	5.25	11.08
1.340	34.50	+ 3.50	5.40	11.16
1.350	36.10	+14.37	5.60	11.23

From "Practical Refrigerating Engineers' Pocketbook," Nickerson & Collins Co.

The freezing points of some brine tank solutions are given by Fig. 8. Curves showing the freezing points as the percentage by volume of solute are given for glycerin, denatured alcohol, calcium chloride, and one-half wood alcohol and one-half glycerin.

Prime Mover.—Electric motors are used to drive practically all household refrigerating machines. Most of the machines

TABLE LVII.—PROPERTIES OF SALT (SODIUM CHLORIDE) SOLUTIONS IN WATER

Specific Gravity at 39°F.	Per Cent of Sodium Chloride	Freezing Temp. Degree F.	Weight, Lbs. per Gallon	Specific Heat
1.010	1.5	30.25	8.44	0.986
1.020	2.6	28.40	8.50	0.979
1.030	4.0	26.60	8.59	0.968
1.040	5.2	25.20	8.67	0.958
1.050	6.5	23.40	8.76	0.945
1.060	7.8	21.60	8.84	0.936
1.070	9.1	19.90	8.92	0.922
1.080	10.4	18.40	9.00	0.912
1.090	11.8	16.40	9.10	0.902
1.100	13.0	14.60	9.18	0.886
1.110	14.1	13.4	9.25	0.876
1.120	15.5	11.6	9.34	0.865
1.130	16.8	10.0	9.42	0.856
1.140	18.0	8.6	9.49	0.846
1.150	19.2	7.0	9.58	0.832
1.160	20.5	5.9	9.67	0.824
1.170	21.8	3.8	9.77	0.817
1.180	23.0	2.4	9.85	0.806
1.190	24.3	1.0	9.93	0.794
1.191	24.5	+ 0.8	9.94	0.792
1.200	25.6	+ 0.2	10.00	0.776
1.204	26.0	− 1.1	10.04	0.771

This table varies slightly from 4°F. to 20°F. from those usually published, which are considered more correct. The differences would affect only calculations on congealing tanks, as it is customary in ice making to make the brine as strong as possible, or near 25% or 26%.

From "Practical Refrigerating Engineers' Pocketbook," Nickerson & Collins Co.

TABLE LVIII.—BRINE TANK DATA

Relative heat storing capacity and cost of various materials which might replace calcium or salt brine.

Material	Specific Gravity	Specific Heat	B.t.u. Heat Storing Capacity per Pound of Material	Cost per Pound of Material Cents	B.t.u. Stored for Each Cent Cost of Materials
Salt brine	1.2	0.78	0.93	0.5	1.9
Calcium Brine	1.2	0.70	0.84	0.5	1.68
Water	1.0	1.00	1.00	....	....
Cast Iron	7.1	0.13	0.92	5.0	0.18
Lead	11.4	0.03	0.34	6.0	0.006
Copper	8.9	0.093	0.83	20.0	0.041
Aluminum	2.6	0.22	0.57	30.0	0.019
Concrete	2.2	0.25	0.55	0.14	3.9
Sandstone	2.2	0.20	0.44	0.1	4.4
Paraffin	0.9	0.69	0.62	10.0	0.062
Oil	0.9	0.4	0.36	6.0	0.06
Kerosene	0.8	0.5	0.40	2.0	0.20

on the market today use ¼ horse power motors. This size motor with a reasonably efficient refrigerating system should be capable of refrigerating properly fifty cubic feet of food storage space. Refrigerating systems of this capacity in use today require from three to six times the amount of current necessary to perform this duty on a large commercial plant. More efficient machines should be developed; however, it is not necessary to very closely approach the efficiency of the large plant.

Some machines have been placed on the market using 1/6 horse power motors. This size has now proven successful for the smaller units up to twenty cubic feet of food storage space.

It is assumed that the food storage spaces are properly insulated. For food compartment temperatures of 40°-50° F., the insulation should be at least 3 inches thickness of corkboard or its equivalent.

The starting torque and the overload capacity are important features in the choice or design of the motor. The overload may be double the normal operating load and it may be necessary to operate at this overload for several hours. This condition usually occurs when the machine is placed in operation in a warm environment temperature. The starting torque is high when the unit is first placed in operation on account of the high pressure on the evaporating side of the system. In normal operation the starting torque may be greatly increased if either the expansion valve or the compressor discharge valve leaks. Air-cooled machines have a more severe starting condition than water-cooled machines especially when a dead air condenser is used.

It is customary to use repulsion-induction type of a.c. motors for driving household refrigerating machines because of their relatively high starting torque. Split-phase motors have been used to a very limited extent on some of the smaller machines.

Some machines have been made with the entire motor housed inside a gas tight metal casing, thus eliminating the packing of a drive shaft. Considerable difficulty has been experienced, however, in operating a motor enclosed with the

refrigerant gas. A later design has the stator outside a thin metal casing, the rotor being inside, thus eliminating packing a drive shaft.

Lubrication of the motor is an important feature as it usually operates from six to twelve hours a day. With this service condition, the motor should be oiled at least once a month. Some motors are oiled automatically through copper tube lines from a gear case pump; the oil is forced or splashed into the tube by the rotating gear. This method is only applicable on a direct-connected motor compressor unit.

The efficiencies of fractional horsepower alternating current motors of the repulsion-indution type at full rated load are usually within the following limits:

Horsepower	Efficiency per cent
1/6	50-60
1/4	60-75
1/2	65-80

Direct current motors should have efficiencies considerably higher than given in this table.

It is customary to limit the normal operating load to 300 watts on the 1/4 hp. and to 200 watts on the 1/6 hp. size. These motors will usually stand 100 per cent overload for short periods of operation.

Table LIX gives the ampere ratings of alternating current motors of capacities ranging from 1/4 to 5 hp. on both single and three-phase current, at 110 and 120 volts.

TABLE LIX—AMPERE RATING OF ALTERNATING CURRENT MOTORS

SINGLE PHASE			THREE PHASE	
Horsepower	110 Volts	220 Volts	110 Volts	220 Volts
1/4	4	2	....	....
1/2	7.5	3.75	4.4	2.2
3/4	10	5	....	....
1	12.5	6.25	8	4
1 1/2	18	9	10.3	5.1
2	24	12	12.5	6.25
3	34	17	18	9
4	43	22	24	12
5	55	28	30	15

The Drive.—Some of the more important types of drives in use are: belt, gear, and direct.

The belt drive has several important advantages. It gives an easier starting torque than a direct-connected or gear drive. Some motors operate at a rather small load and therefore at a low efficiency, simply because they must be large enough to insure starting under all conditions of service. The belt also gives a certain protection to the motor, as it will sometimes slip or come off the pulleys with an excessive overload on the motor. Another important advantage of a belt drive is that it can be easily repaired or replaced without the services of an expert mechanic.

A belt drive generally costs less than a gear drive. The belt drive is easier to manufacture and assemble as it does not require such close limits on lining up the motor.

Some machines use a series of from two to five small belts. If one breaks it does not greatly affect operation. This multiple belt system has not proven very satisfactory in actual use, probably because one of the belts is usually driving more than its share of the load.

A belt drive is ordinarily from 95 to 98 per cent efficient. This is a much higher efficiency than is usually obtained with a gear drive.

An exposed belt drive is dangerous on a machine which starts automatically, and every precaution should be taken to safeguard it. One method of obtaining this result is to make the condenser coil of tubing and arranging it so as to form a guard around the belt and its pulleys.

Flat belts have been used on a large number of successful machines. They are generally made of either leather, canvas, or fabric.

An idler is generally used with a flat belt drive. It is necessary in order to increase the angle of contact on the motor pulley. The idler is usually operated by a spring or a weight. It also serves another purpose in automatically keeping the belt tight by compensating for any stretching of the belt in service. One cannot depend upon attention being given to a belt by the user, especially in the way of making adjustments. One of the difficult features on a flat belt drive is to insure necessary lubrication of the idler pulley.

The V-type rubber or fabric belt as developed for use in driving the radiator fan on automobiles is being used with success on household plants. It has most of the features of a flat belt with the added advantage of not requiring an idler pulley. A belt of this type drives by means of friction on the side of the V-shaped groove. The inside face of the belt should not touch the pulley. These belts are generally of the endless type, they run quite loose and do not stretch enough in service to require any adjustment of pulley centers.

Spiral gear drives are used on compressors both with parallel and right angle shafts.

Spiral gears have an advantage over worm gears in that they do not require as close limits on shaft centers and can be made without a hob.

Gear drives produce end thrust on the shafts which is usually carried on a thrust or ball bearing. It is difficult to keep the end clearance on shafts, subjected to a thrust load, to a small enough limit so that the noise from end play on the shafts will not be objectionable.

The thrust bearings should be well lubricated. The starting torque may sometimes be greatly increased when the thrust bearings have not received instant lubrication on starting. This may occur when the thrust bearings are lubricated by a splash system which does not function until the machine has started to operate.

It has been difficult to build gear drives for the reciprocating type compressors so that excessive noise would not result on account of backlash caused by the necessary clearance between the teeth.

Gear drives usually operate at an efficiency of 70 to 90 per cent.

The direct-connected drive is in common use on machines having a gear or rotary pump and on machines with the moving parts enclosed in the refrigerant gas space. Most of the designers have placed the packing gland on the relatively slow-speed compressor shaft, as it is more difficult to pack the motor shaft which rotates at a much higher speed. When the motor or the moving part of the motor is enclosed in the gas space, this packing gland trouble is eliminated. Difficulties have been experienced in starting machines which have

a thin metal shell between the rotor and field of the motor, especially on three-phase, alternating-current motors.

The direct-connected unit has proven more successful commercially in Europe than in the United States.

Valves.—The suction and discharge valves should be designed for service, quietness, positive opening and closing action, and efficiency.

The suction valve is usually simply a port or slot in the cylinder wall which is uncovered by the piston during its relatively slow rate of travel at the end of the stroke. This type of valve has a relatively low efficiency but is free from service troubles, operates quietly, and is positive in action.

The port valve has a loss in efficiency due to the necessity of producing a vacuum in the cylinder, as the top of the piston returns on the suction stroke. The gas rushes in the cylinder at the end of the stroke during the short interval of time that the port is uncovered by the piston sometimes causing wire drawing, a further loss in efficiency.

The port valve can be used to good advantage on compressors with lapped pistons, as some difficulty has been experienced in using piston rings which must pass over ports in the cylinder walls.

A floating valve of the poppet type is used in the pistons of some of the larger compressors. These valves have not proven so successful as the port type, as a small particle of scale, sand, carbon or dirt can be deposited on the seat and will prevent the valve closing tightly. This frequently happens on a new machine and is prevented to a certain extent by placing a fine mesh screen in the suction line of the compressor.

Some designs use a slight rotating movement of the cylinder itself to uncover ports.

Many varieties of discharge valves are used. These are simply check valves permitting low-pressure gas to enter the cylinder on the suction stroke.

The poppet type valve has proven successful with a light spring to assist in closing. Disc steel valves are also used. These are more difficult to manufacture than the poppet type, however they make less noise.

The steel spring flapper valve is used to a considerable extent. These valves require very close limits in manufacture. They give good service once they are assembled properly, and are not easily affected by corrosion or dirt.

The discharge valve should be capable of opening more than the normal lift, in order to discharge liquid refrigerant or lubricant which is sometimes pumped by the compressor.

An important feature to be considered in valve design, is to construct a valve which will give service for years without requiring adjustments or service of any kind. A service call is quite expensive and with most of the refrigerating gases in common use, such repairs can only be made by a trained service man. This is probably the fundamental reason for using port suction valves even at large loss in efficiency, by some of the most successful manufacturers.

Shut-off valves are very important in order to facilitate repairs to a certain part of the refrigerating system. It is customary to use three of these valves, one on the suction or inlet line to the compressor, one on the discharge line between the compressor and condenser, and the third between the condenser and expansion valve. The valves near the compressor usually have double seats so that they may be closed against a gauge or charging connection.

It is important to have the valve stem opening limited by a stop to prevent backing out the stem and thus losing some of the refrigerant. When the refrigerating system is not used for a period of weeks, it is sometimes advisable to close the two valves on the compressor, suction, and discharge lines, to prevent loss of refrigerant through the packing gland.

Alco Liquid Control Valve.—Fig. 19 is a cross-section of the automatic liquid control valve manufactured by the Alco Valve Company, at St. Louis, Mo.

The liquid refrigerant enters at F. In operation the valve needle J opens from the valve seat G and the liquid refrigerant discharges through tube K.

These discharge tubes are furnished in different sizes for different capacity machines.

Expansion of the refrigerant is prevented in the valve body by using the small discharge tube K. It is claimed that this

feature eliminates the following troubles experienced with the regular type expansion valve.

1. Frost forming on the valve.
2. Water freezing on the diaphragm.
3. Oil congealing in the valve.
4. Scoring of pin or seat.

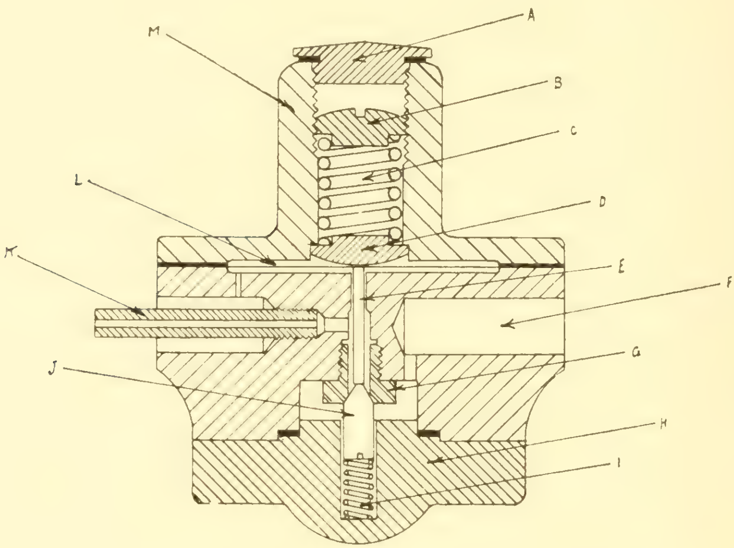


FIG. 19.—CROSS SECTION ALCO LIQUID CONTROL VALVE.

American Automatic Expansion Valve.—Fig. 20 shows the automatic expansion valve made by the American Radiator Company of Buffalo, N. Y.

These valves are designed for use with the following refrigerants: Methyl chloride, sulphur dioxide, ethyl chloride, or any refrigerant not having a detrimental effect on brass. Fig. 21 is a sectional view of this valve. Adjustment is made by turning the adjusting screw, regulating the spring pressure against the bellows.

The valve closes against pressure, thereby eliminating chattering and wire drawing, and making the valve seat self-cleaning.

Pressure is on the outside of the bellows, a desirable construction feature.

Valves are supplied with 3/8-inch pipe thread or flanged connections.

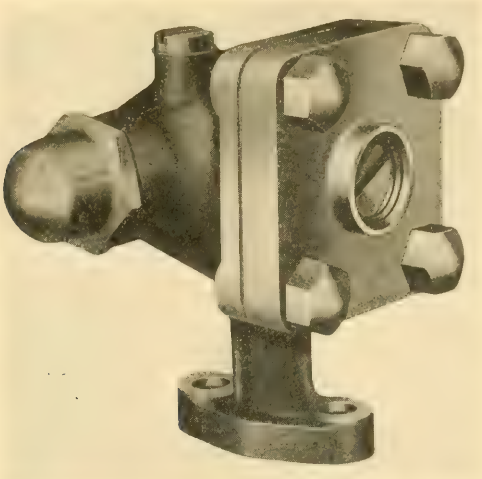


FIG. 20.—AMERICAN AUTOMATIC EXPANSION VALVE.

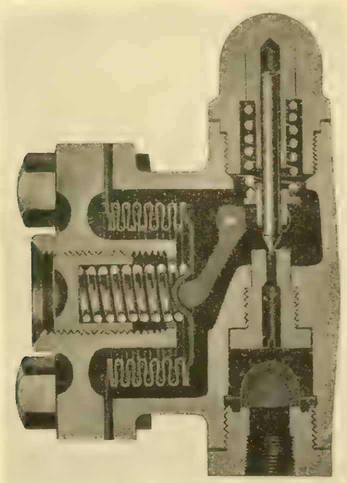


FIG. 21.—SECTIONAL VIEW OF AMERICAN AUTOMATIC EXPANSION VALVE.

American Float Valve and Refrigerating Section.—Fig. 22 shows the float valve which may be used either as a low or high pressure float.

The float is cylindrical, thereby making the valve more compact than is the case when the usual bulb type is used.

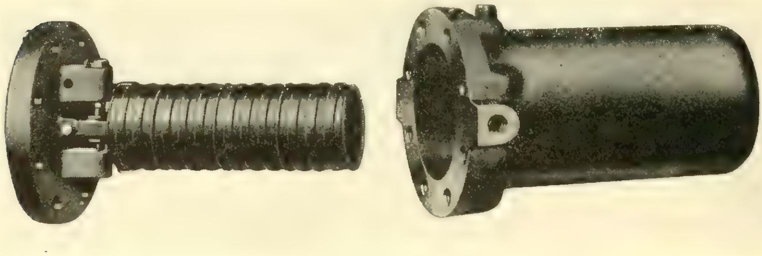


FIG. 22.—AMERICAN FLOAT VALVE.

A new style of domestic refrigerating section is now manufactured as in Fig. 23. This section is made in two types, one as illustrated, containing the float chamber, and a similar type

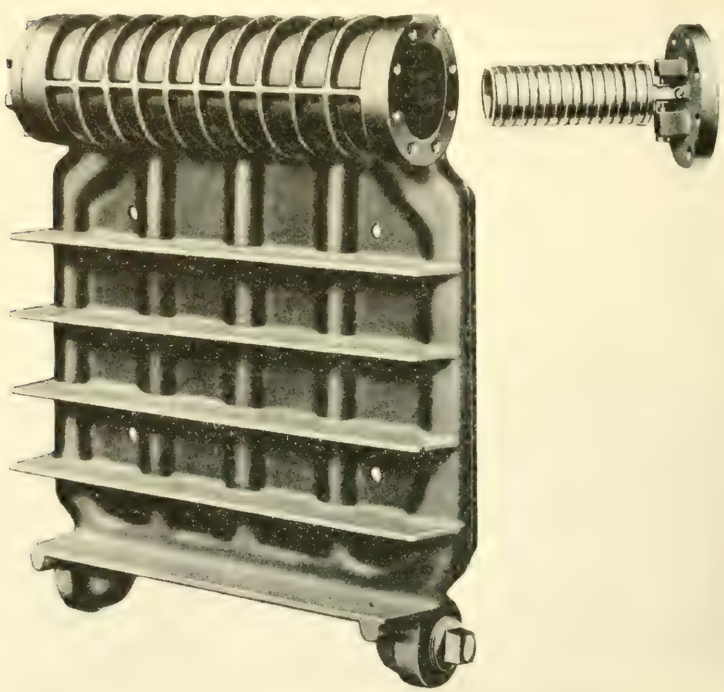


FIG. 23.—AMERICAN REFRIGERATING SECTION

without the float chamber. These are made for five or seven ice trays, each tray containing eight cubes, one cube wide and eight cubes deep.

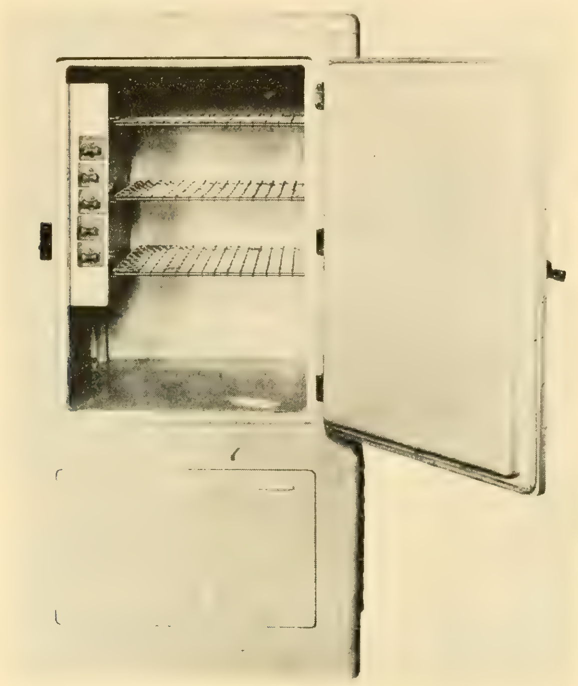


FIG. 24. AMERICAN REFRIGERATING SECTION INSTALLED.

Fig. 24. shows one of these refrigerating sections installed in a cabinet. This design gives more space in the refrigerator for the storage of food than cooling units of conventional design.

Flow of Air Through Orifices. — Table LX gives the amount of free air in cubic feet which will flow through circular orifices in a receiver into air at atmospheric pressure, corresponding to various air gauge pressures in pounds per square inch in the receiver. The diameter of the orifices varies from 1/64 in. to 2 ins.

TABLE LX.—CUBIC FEET OF FREE AIR FLOWING THROUGH A CIRCULAR ORIFICE FROM RECEIVER INTO ATMOSPHERE PER MINUTE (Cox)

Diameter of Orifice—Inches	Air Gauge Pressure in Pounds							
	2	5	10	15	20	25	30	35
1/64	.038	.0597	.0842	.103	.119	.133	.156	.173
1/32	.153	.242	.342	.418	.485	.54	.632	.71
1/16	.647	.965	1.360	1.67	1.93	2.16	2.52	2.80
1/8	2.435	3.86	5.45	6.65	7.70	8.60	10.0	11.2
1/4	9.74	15.40	21.8	26.70	30.80	34.5	40.	44.7
3/8	21.95	34.60	49.	60.	69.	77.	90.	100.
1/2	39.	61.60	87.	107.	123.	138.	161.	179.
5/8	61.	96.50	136.	167.	193.	216.	252.	280.
3/4	87.60	139.	196.	240.	277.	310.	362.	400.
7/8	119.50	189.	267.	326.	378.	422.	493.	550.
1	156.	247.	350.	427.	494.	550.	645.	715.
1 1/4	242.	384.	543.	665.	770.	860.	1000	
1 1/2	350.	550.	780.	960.				
2	625.	985.						

Diameter of Orifice—Inches	Air Gauge Pressure in Pounds								
	40	45	50	60	70	80	90	100	125
1/64	.190	.208	.225	.26	.295	.33	.364	.40	.486
1/32	.77	.843	.914	1.05	1.19	1.33	1.47	1.61	1.97
1/16	3.07	3.36	3.64	4.20	4.76	5.32	5.87	6.45	7.85
1/8	12.27	13.4	14.50	16.8	19.	21.2	23.50	25.8	31.4
1/4	49.09	53.8	58.2	67.	76.	85.	94.	103.	125.
3/8	110.45	121.	130.	151.	171.	191.	211.	231.	282.
1/2	196.35	215.	232.	268.	304.	340.	376.	412.	502.
5/8	306.80	336.	364.	420.	476.	532.	587.	645.	785.
3/4	441.79	482.	522.	604.	685.	765.	843.	925.	
7/8	601.32	638.	710.	822.	930.	1,040.			
1	785.40	860.	930.						

Temperature Control.—The automatic temperature control is an important part of the refrigerating system.

The food compartments should be maintained at a temperature never warmer than 50° F. and never colder than 40° F. These temperature limits have been definitely established by experience. Perishable foods keep well at a temperature below 50° F. Food compartment temperatures below 40° F. will cause unnesessary heat losses even with a well-insulated cabinet, and the outside surface of the cabinet will frequently be damaged by sweating.

The automatic control should be arranged to freeze water or desserts in a reasonable length of time, and to constantly maintain the food compartment temperatures between 40° and 50° F.

It is desirable to freeze water or desserts in less than the shortest time interval between meals which is about six hours. An average brine temperature of 20° F. will freeze water in the ordinary cube form in from four to six hours. The temperature should not vary more than four degress from this value. It is more difficult to freeze desserts than water, especially if the ice tray grids are removed.

Some of the first mechanical refrigerators sold had the liquid tube of the thermostat line suspended in the cold air flue. This liquid tube was connected by tubing to a diaphragm or metal bellows which operated the motor switch.

A 1/4-hp. motor was generally used and this required a quick make and break type of switch. This was called the food compartment temperature control system.

Some of the volatile liquids used in these thermostat systems were: Sulphur dioxide, methyl chloride, ethyl chloride, and ether.

The usual method of operating the switch is by means of a violatile liquid. This liquid is trapped in a closed gas system, so that the liquid tube itself is always immersed in the brine or in close contact with the place where the temperature is to be regulated. The diaphragm or metal bellows can be placed above or below this liquid trap. The gas pressure in the closed system is always definitely determined by the temperature of the volatile liquid. The switch can be adjusted

to operate at any desired temperature, within the working range of the liquid used.

An improvement in the brine temperature regulating system is to use an automatic damper in the cold air flue. This

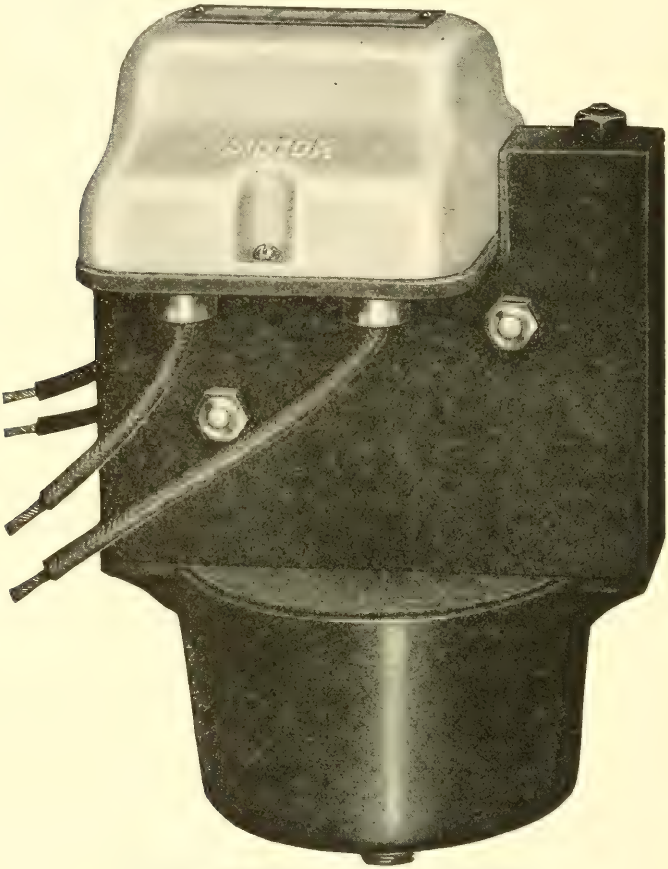


FIG. 25.--PENN ELECTRICAL CONTROL.

damper opens and increases the air circulation when the food compartment temperature increases.

Another method of improving this temperature control, is to have the liquid tube located close to the last turns of the evaporating coil. Then if the evaporating coil frosts through, the liquid controlling the temperature in the thermostat will be rapidly cooled, thus stopping the compressor.

Other manufacturers use a temperature control partly influenced by the temperature of the brine and partly by the temperature of the circulating air. This kind of regulation has advantages of both of the systems previously described.

Some machines are operated by a time clock. The clock operates a switch and can be set for a certain number of cycles per day. Usually this type of control is adjusted for a summer or winter condition. This system does not compensate for cold nights and gives rather unsatisfactory food compartment temperature regulation.

Some switches are operated by using a bimetallic thermostat. The small temperature differential, usually from 4° to 10° F., makes the design of a bimetallic thermostat a difficult problem. Switches of this type have not proven a success commercially.

An improvement in the bimetallic switch is being used now. It consists of mounting to a bimetallic member a glass tube, containing a small amount of mercury which flows from one end to the other. In this way a quick make and break contact is secured. These tubes have the air exhausted from them and contain an inert gas so that any arcing will not affect the mercury or terminal contact points.

Fig. 25 shows a switch made by the Penn Electric Machine Co., of Des Moines, Ia.

This switch is provided with a bellows type diaphragm, which can either be filled with a volatile fluid or attached to a bulb, which contains the volatile fluid and which causes the diaphragm to expand, closing the switch contacts when the temperature increases to the predetermined amount.

The switch may be placed inside or outside the refrigerator. When placed outside, the bulb containing the volatile fluid is inside at the desired location for proper temperature control. This installation simplifies the wiring connections.

The contacts are of the two-pole double break per line type. The switch is approved by Underwriters for use on motors up to 5 hp., 3-phase, 550-volts.

This type switch is compact, easily installed, and convenient for wiring.

Thermostat Operation.—Figs. 26 and 27 show the operation of a volatile liquid thermostat.

The volatile liquid is contained in a tube immersed in the brine. Sufficient liquid is placed in this tube so that at the highest operating temperature there will still be liquid in the thermostat bulb. In this way, the pressure in the thermostat line is always the corresponding pressure for the temperture of the liquid in the bulb.

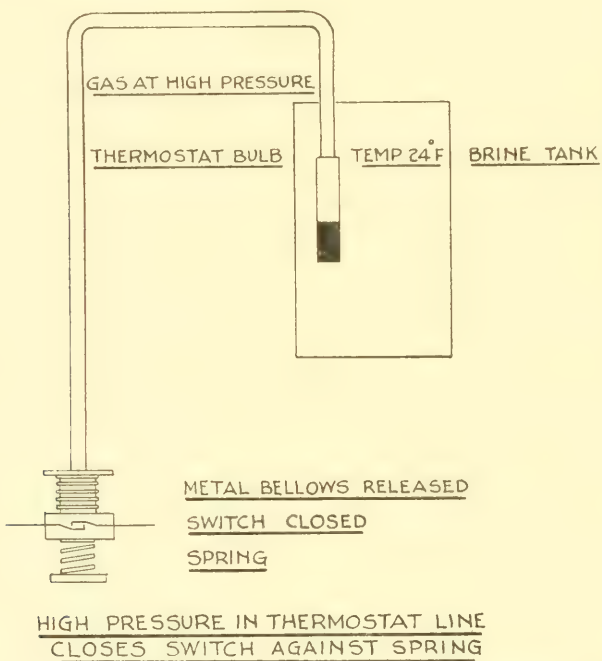


FIG. 26.—OPERATION OF VOLATILE LIQUID THERMOSTAT.

In Fig. 26 the brine temperature has increased to 24°, vaporizing some of the liquid in the thermostat bulb and increasing the gas pressure, until finally the metal bellows expands against the spring, closing the motor switch.

The motor then operates the compressor cooling the brine. The thermostat bulb is cooled decreasing the gas pressure in the thermostat system. The gas pressure is decreased as gas is condensed into liquid form in the thermostat bulb.

Finally the pressure is lowered to a pressure so that the spring will compress the metal bellows and open the motor switch.

By adjusting the compression of the spring, the motor may be started or stopped at any desired brine temperature.

When too much liquid is charged into a thermostat system of this kind, the pressure will be a function of the thermo-

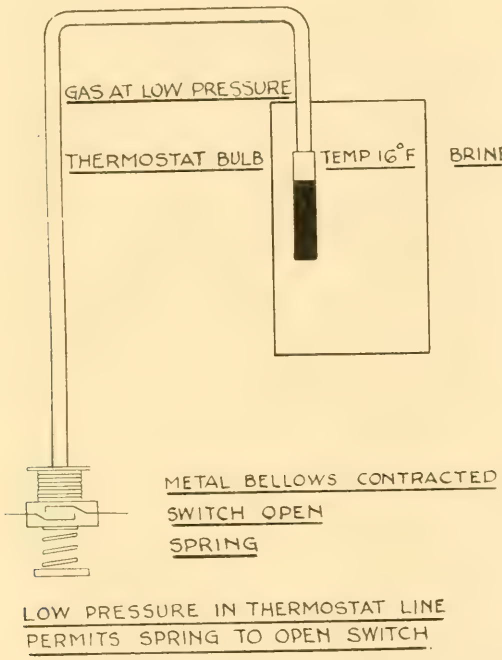


FIG. 27.—OPERATION OF VOLATILE LIQUID THERMOSTAT.

stat line temperature and the control will not operate satisfactorily.

If the volatile liquid charge is too small, all the liquid will vaporize at the higher brine temperature and the control will not function properly.

Air or foreign gases in the thermostat system will produce an abnormally high pressure at all times. Oil in the thermostat will cause a sluggish action.

Water Controls.—When a water-cooled condenser is used with the compression type household machine, it is desirable to have the following controls.

1. Open the water valve when the compressor starts to operate.
2. Close the water valve when the compressor shuts down.
3. Regulate the amount of water supplied to the condenser compensating for a warmer or colder tap water temperature.
4. Regulate the amount of water supplied to compensate for different loads on the compressor.
5. Compensate for different water supply line pressures.
6. Prevent the compressor from operating when the water supply fails.
7. Permit the compressor to function normally when the water supply is again available.

A method of water control in common use is to open, close, and regulate the water valve by means of a diaphragm or metal bellows responsive to the condensing pressure.

The valve is set to open at a certain pressure slightly higher than the pressure ever obtained in the condenser during the inoperative part of the cycle. An increase in condensing pressure will open the water valve still more. This increase in condensing pressure may be due to an increased load on the compressor or to a higher tap water temperature or to a decrease in the water supply line pressure.

Another system of water control is to use a water valve opened and closed by means of a solenoid coil. This coil is placed in the motor circuit and holds the valve open while the compressor is operating. This system does not compensate for differential water temperatures and changes in the refrigerating load.

A water cooling system used to some extent consists of a valve opened by the centrifugal force of weights mounted on the compressor or motor shaft. This gives a control functioning in a way similar to the electric valve but entirely mechanical in operation. This system does not regulate the amount of water supplied, in accordance with the requirements due to changes in temperature, pressure, and load.

A dead water tank has been used to some extent. The condenser is immersed in a rather large tank of water. During the inoperative part of the cycle, this water is cooled to a temperature approaching that of the room. As a household

machine usually operates about 25 per cent of the time, there is a sufficient time interval between runs for the condensing water to cool to nearly the room temperature.

Mercoid Control.—Fig. 28 and 29 shows a special control for domestic refrigerating machines made by the American Radiator Company of Buffalo and the Federal Gauge Company of Chicago.

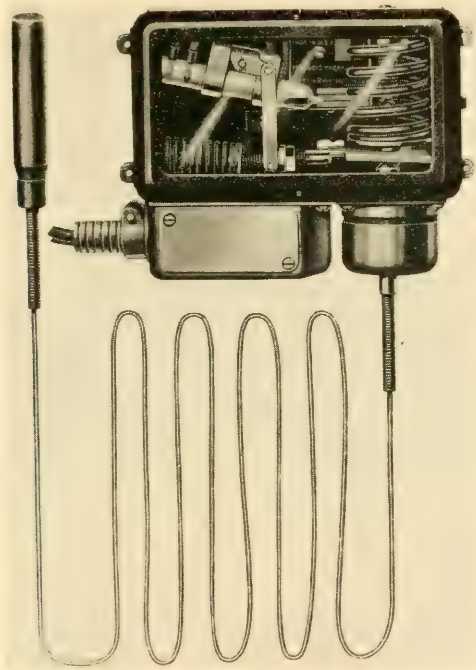


FIG. 28.—MERCOID CONTROL, FLEXIBLE TUBE TYPE.

The Mercoid Switch consists of a glass tube in which are sealed leads of special material. A quantity of mercury makes or breaks the circuit when the tube is tilted. Hermetically sealed within the tube are inert gases which stifle the arc instantly. There is no oxidation or corrosion. The contact is permanently clean and instantaneous in operation.

Fig. 28 shows the remote control, flexible tube type. Fig. 29 shows the pressure type thermostat.

This control can be furnished to automatically open or close an electric circuit with a change in temperature. The circuit is controlled directly to the motor or other electric equipment.

Ordinary lighting or power current can be run through the control.

The operation of this control is very simple. A power element is expanded automatically by temperature, which in turn,

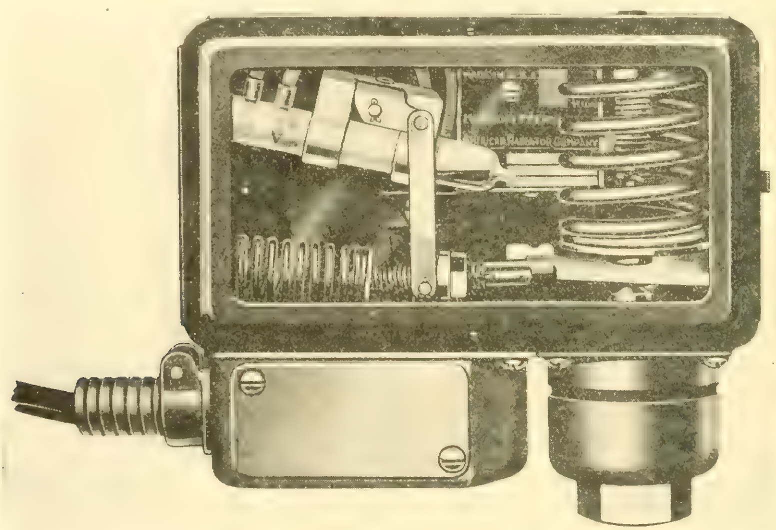


FIG. 29.—PRESSURE TYPE THERMOSTAT.

tilts the switch with a snap action. A spring throws the switch in the opposite direction as pressure or temperature decreases.

A special feature of the thermostatic power element is its dependability. The operation remains constant and does not change; years of service will not affect its power or sensitivity.

The power element consists of a seamless metallic bellows, the folds of which are so made that expansion and contraction will not affect the life of the metal. When used thermostatically the bellows contain liquids of various boiling points as determined by the desired operating temperatures.

Refrigerator Control Switch.—Fig. 30 is a sectional view of the electric refrigerator control unit made by the Automatic Reclosing Circuit Breaker Company of Columbus, Ohio.

The expansion bellows is filled with a freezing solution. When this solution freezes the bellows expand and close the

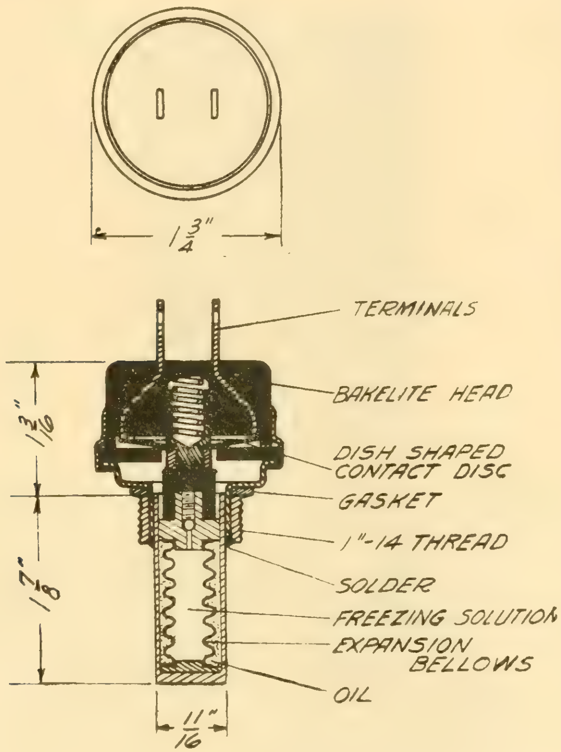


FIG. 30.—SECTIONAL VIEW OF ELECTRICAL REFRIGERATOR CONTROL.

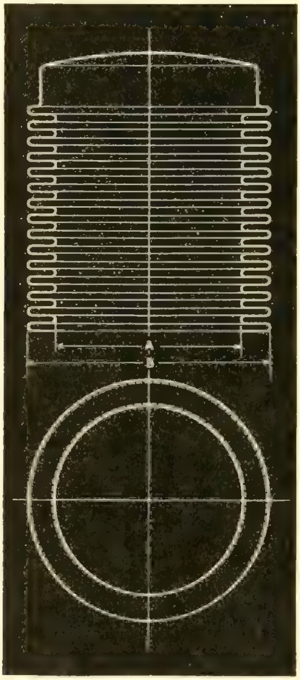
electric circuit by forcing the dish-shaped contact against the two electric terminal inserts.

There is no adjustment for temperature as this setting is obtained by changing the proportions of the materials used for making the freezing solution.

This design affords a control free from outside adjustments and of very simple construction.

Multiflex Bellows.—Fig. 31 shows the seamless one-piece multiflex metal bellows made by the Bishop & Babcock Sales Company.

These bellows are used in many different parts of electrical refrigerating systems, usually in connection with the thermostat while some manufacturers use them to seal the compressor shaft.



A—Inside Diameter B—Outside Diameter.

FIG. 31.—SEAMLESS ONE-PIECE MULTIFLEX METAL BELLOWS.

Table LXI gives standard sizes of bellows. Wall thickness can be supplied for external or internal pressure to 500 pounds per square inch.

The Fedders Manufacturing Company of Buffalo, New York, make appliances for household refrigerating machines.

Fig. 32 shows a condenser and receiver unit. The condenser consists of coils of copper tubing with a special type of copper fins to increase the cooling efficiency.

TABLE LXI—STANDARD BELLOWS

Outside Diameter	Inside Diameter	Free Movement	No. of Convolutions	Normal Length
1″	3/4″	1/4″	18	1 1/8″
1 1/4″	15/16″	5/16″	16	1 5/16″
1 3/8″	1″	3/8″	18	1 3/4″
1 1/2″	1 1/32″	3/8″	18	1 3/4″
1 5/8″	1 3/16″	3/8″	18	1 3/4″
1 13/16″	1 3/8″	3/8″	18	2″
2″	1 7/16″	7/16″	16	2 1/16″
2 3/16″	1 1/2″	3/8″	14	2 1/4″
2 3/8″	1 3/4″	7/16″	15	2 1/4″
2 7/8″	2 1/4″	3/4″	18	3 1/8″
4 1/8″	3 3/8″	3/4″	17	2 5/8″
7 3/4″	6 7/8″	1/2″	10	2 3/4″

Fig. 33 is a photograph of the expansion valve which may be used with any of the refrigerants in common use in household machines. A change of springs is necessary with very low pressure refrigerants.

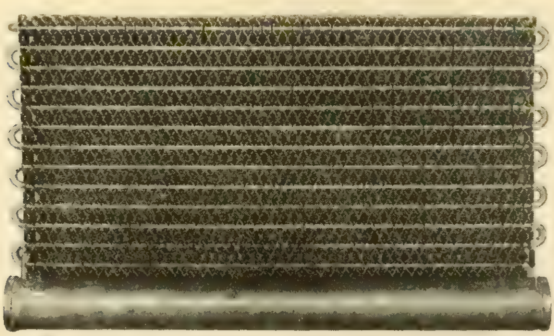


FIG. 32. CONDENSER AND RECEIVER UNIT.

Fig. 34 is a tubular liquid strainer used in the inlet connection to the expansion valve. A liquid filter, Fig. 35, is used to filter out the small particles of scale or oxide which may accumulate in the refrigerating system. This filter contains two circular pieces of fine meshed screen with wool felt between them.

Fig. 36 shows a typical brine tank. These tanks are made of tinned copper with lock seams. The wall thickness of the copper is .028 inches. These tanks are made in standard sizes

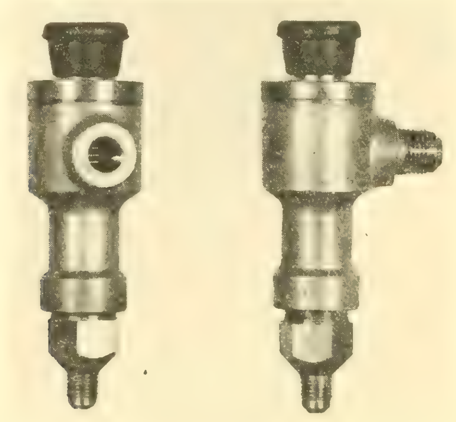


FIG. 33.—EXPANSION VALVE.

to suit the requirements of the different styles and types of refrigerators in use today.

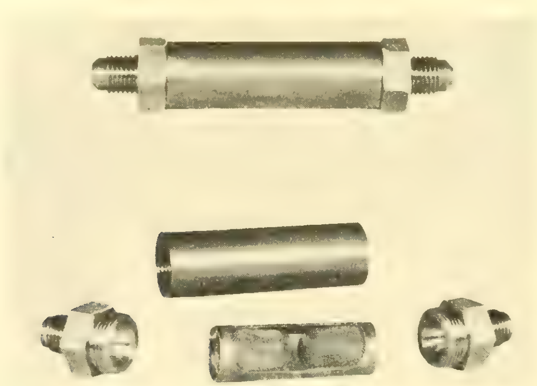


FIG. 34.—TUBULAR LIQUID STRAINER.

FIG. 35.—A LIQUID FILTER.

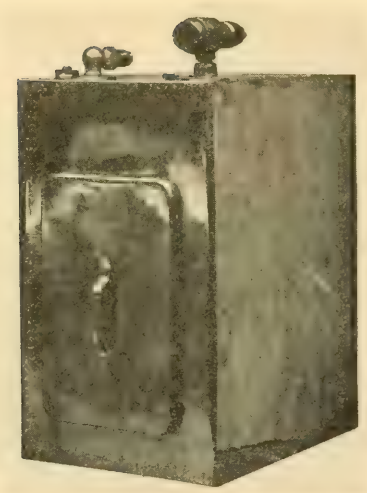


FIG. 36.—A TYPICAL BRINE TANK.

CHAPTER VII

HOUSEHOLD REFRIGERATING MACHINES COMPRESSION TYPE

Household Refrigerating Machines.—In this chapter, attention will be given to the general types and characteristic construction of a number of household compression refrigerating machines. The makes of the various household refrigerating machines which are described here have been selected promiscuously, and represent the characteristic design of the different classes of machines. It does not include descriptions of all of the different kinds of household machines, since, at present, there are several hundred different concerns producing or developing machines of this type.

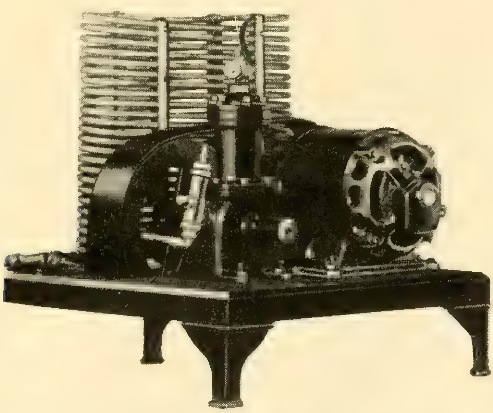


FIG. 37.—ABSOPURE AIR-COOLED MECHANICAL UNIT.

In the following, attention has been given to the mechanical design of the different parts of the compression type.

Absopure.—Fig. 37 shows a ¼ hp. air-cooled mechanical unit used on the household machine manufactured by the Gen-

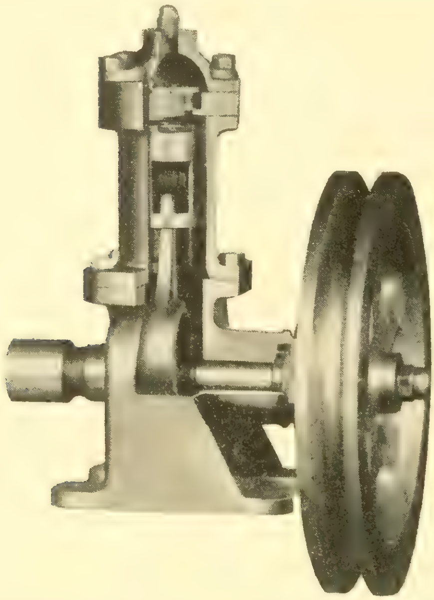


FIG. 38.—SECTIONAL VIEW OF ABSOPURE COMPRESSOR.

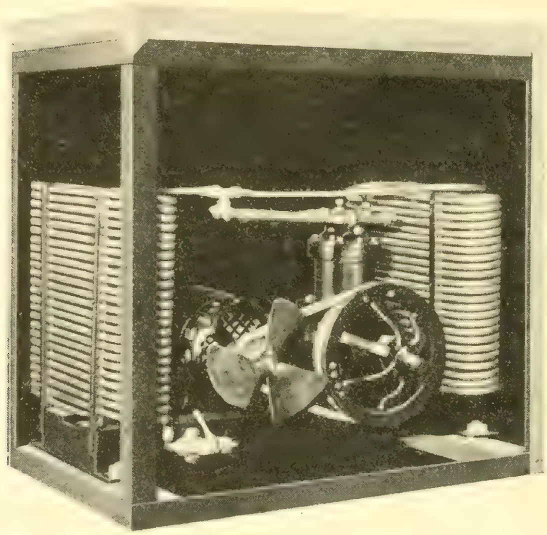


FIG. 39.—HALF-HORSEPOWER ABSOPURE CONDENSING UNIT FOR ICE CREAM CABINET.

eral Necessities Corporation of Detroit, Michigan. This machine uses methyl chloride as the refrigerant.

A sectional view of the compressor is shown in Fig. 38. The motor drives the compressor by means of a "V" type belt. The discharge valve is of a disk type. The shut-off valves are made of forged brass.

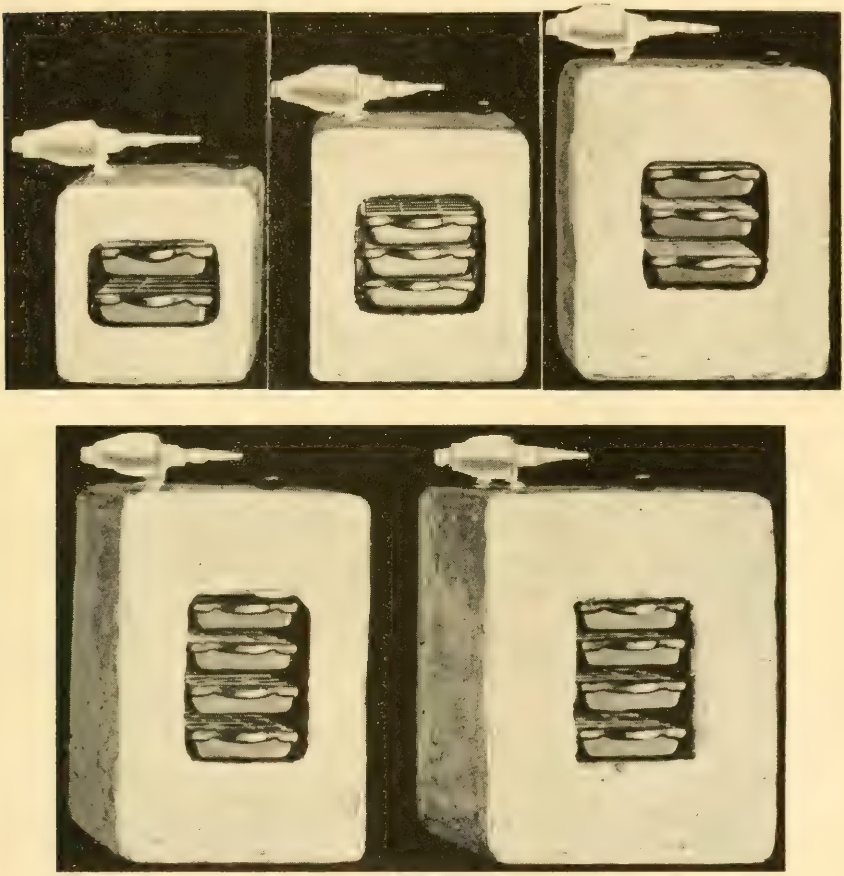


FIG. 40.—TYPICAL ABSOPURE FREEZING UNIT IN VARIOUS SIZES.

The ½ hp. air-cooled mechanical unit is shown in Fig. 39. This is one of the condensing units used for ice cream cabinet work. The condensing unit is placed in a compartment which may be fastened to the ice cream cabinet.

Fig. 40 shows a typical freezing unit. These are made in sizes suitable for use in all types of household refrigerators.

FIG. 41. TYPICAL ABSOPURE REFRIGERATOR.

Fig. 41 is a typical refrigerator in which the mechanism may be installed as a complete self-contained unit.

Audiffren.—Fig. 42 gives a sectional view of the household machine manufactured by the Audiffren Refrigerating Machine Company of New York City. A view of a cabinet equipment with this machine is shown in Fig. 43.

This machine has an enclosed sulphur dioxide compressor. All of the operating parts are sealed up within this revolving "dumbbell," consisting of two bronze bells on a hollow shaft.

The Rotor consists of two hollow bronze bells connected by a hollow steel shaft. One bell containing the compressor also acts as the "condenser"; in the other the liquid boils off under reduced pressure and this is the "evaporator" where intense cold is produced. The hollow shaft contains a tube through which the liquid refrigerant is carried from the con-

denser to the evaporator, and an annular space around the tube through which the spent gas is drawn back by the compressor. Thus compressor, condensing surface, liquid receiver, oil separator, expansion valve and refrigerating surface are all represented in this hermetically sealed Rotor.

The compressor rides on the shaft inside of the spherical bell, being held in an approximately vertical position against the turning of the Rotor by means of a heavy lead counterweight. The compressor has two double acting, oscillating cylinders. The compressor pistons are driven by an eccentric secured to the shaft.

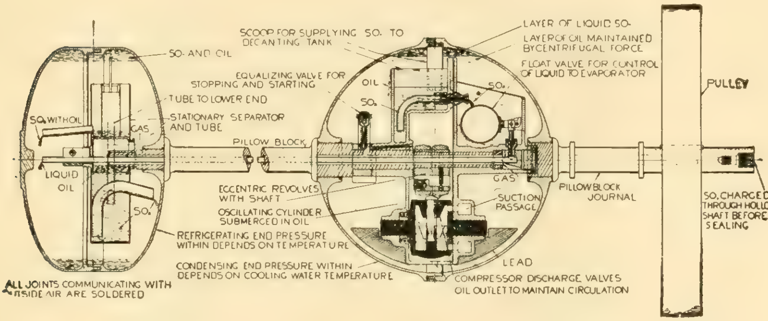


FIG. 42.—SECTIONAL VIEW OF AUDIFFREN HOUSEHOLD MACHINE.

As the Rotor revolves, this compressor, being held in position by the counterweight, draws gas from the evaporator, compresses and discharges it under pressure into the condenser bell within which the compressor is located.

The condenser bell runs partly immersed in cooling water and the compressed gas is cooled and condenses on the inner walls of this bell. The operating pressure is about 50 pounds per square inch, varying with the cooling water temperature.

The condensed refrigerant and the oil are held out against the shell of the condenser bell by centrifugal force and are finally caught by means of a small scoop mounted on top of the frame of the compressor and poured down into a decanting cup where the oil is separated and poured back over the compressor cylinders to lubricate and cool them. The refrigerant is then passed by means of a float valve, which serves for an

automatic "expansion valve," to the evaporator bell of the machine, again to boil off and continue its cycle.

The evaporator is a simple bell providing a chamber for the liquid to evaporate and produce cold. The lubricant that reaches the cold end of the machine is automatically separated and returned to the condenser end through the cylinders, providing internal lubrication for the cylinders and the pistons.

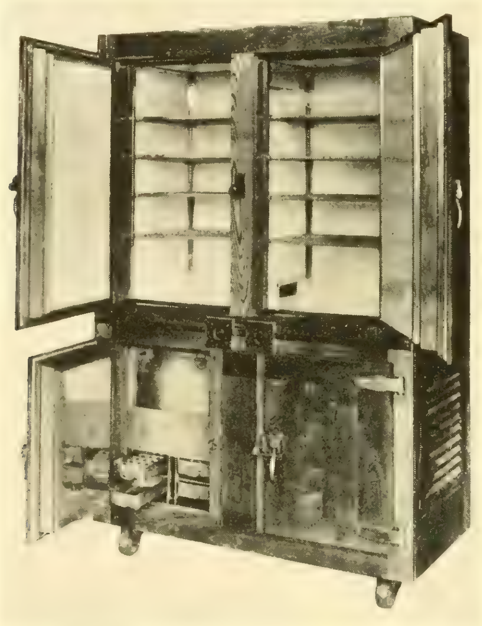
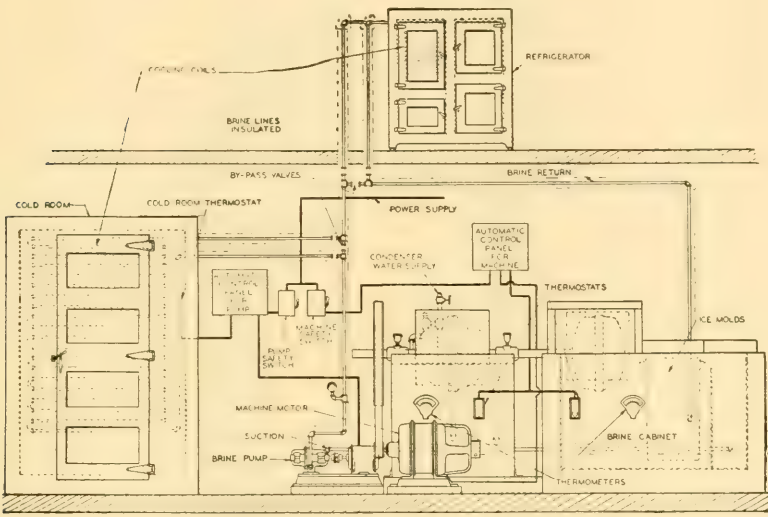


FIG. 43.—VIEW OF CABINET EQUIPPED WITH AUDIFFREN MACHINE.

The temperature and pressure in the condenser will, obviously, be dependent upon the temperature of the condensing water. Consequently the position assumed by the compressor under the control of the counterweight will be dependent upon the temperature of the condensing water. If the supply of condensing water gives out so that the temperature rises above the normal operating limit, the counterweight will finally rise to the horizontal position and any increase in pressure beyond this point will cause the counterweight to revolve with the machine, so that no increase of pressure beyond that for which

the counterweight is designed can be caused by the operation of the machine. This acts as a safety device absolutely protecting the machine from dangerous pressures as a result of failure of condensing water. Until the law of gravity fails, this machine is absolutely safe.

To freeze ice, the ice cans are placed directly in the brine tank. To cool refrigerators, this cold brine is circulated through pipe coils placed in the refrigerators.



TYPICAL ARRANGEMENT
AUDIFFREN REFRIGERATING SYSTEM
WITH COLD ROOM AND PANTRY REFRIGERATOR

FIG. 44.

Fig. 44 shows a typical arrangement for cooling a large cold room, a pantry refrigerator and an ice making plant. A circulating brine system is used. During the last 15 years many systems similar to this have been used for large residences and country estates.

Autofrigor.—This machine, Fig. 45, is manufactured by Esher Wyss & Company of Zurich, Switzerland.

The refrigerant is methyl chloride. The compressor "5" is double-acting, operating at motor speed. Gas from the suction chamber "6" is compressed into the pressure chamber

"7." The compressed gas then passes through the vertical pipe to the high pressure gas chamber "8" and into the annular space surrounding the chamber. The condensed liquid collects in chamber "9." The gas is condensed by circulating water which enters by connection "11" and leaves by outlet "12." Nozzle "13" is used in place of an expansion valve to the evaporator "R."

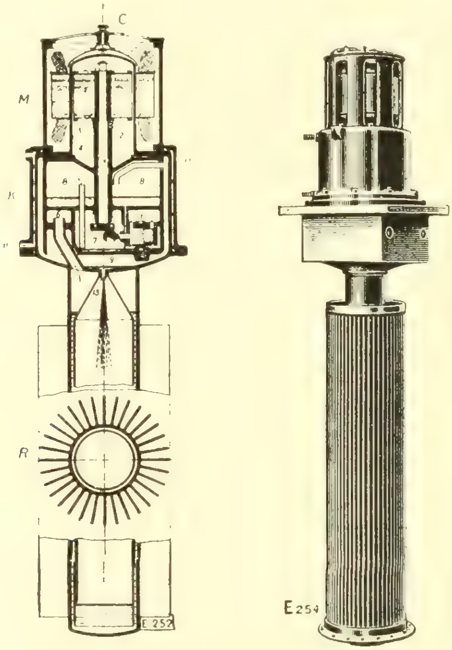


Abb. 2 Abb. 3

FIG. 45.—AUTOFRIGOR.

The motor "M" has its rotor "3" enclosed by a steel shell "4," which seals the gas chamber "8." This machine is manufactured in several sizes.

Brunswick-Kroeschell.—Fig. 46 shows one of the small self-contained units made by the Brunswick-Kroeschell Company of New Brunswick, New Jersey, who have been making household refrigerating machines continuously for more than 25 years. Self-contained units are supplied for full automatic control, semi-automatic or manual operation.

The ammonia or carbon dioxide system can be supplied for either direct expansion of the refrigerant or cooling through brine circulation.

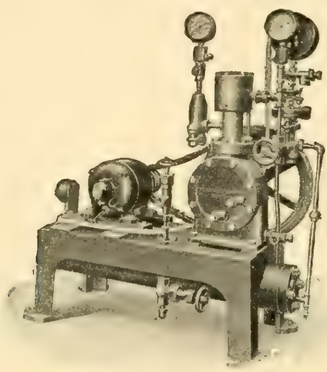


FIG. 46.—SMALL SELF-CONTAINED BRUNSWICK-KROESCHELL UNIT.

Fig. 47 shows a large self-contained unit. This consists of a compression side, electric motor with its starting equip-

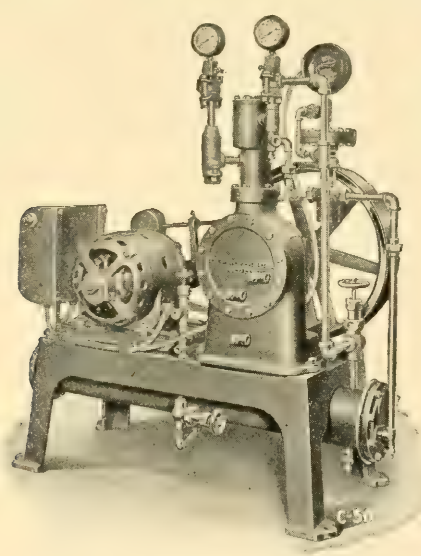


FIG. 47.—LARGE SELF-CONTAINED BRUNSWICK-KROESCHELL UNIT.

ment, special power transmission for short center operations, and interconnection for ammonia, water and electric supply;

these are all mounted on a cast iron pedestal and interconnected ready for service.

The compressor is of the enclosed, vertical, single acting type. Splash lubrication is used.

The condenser is of the shell and tube multi-pass type. Removable heads permit convenient cleaning of the condenser tubes when required in cases where the water leaves a sediment. The shells are of ample size for the combined purpose of service as condenser and ammonia receiver.

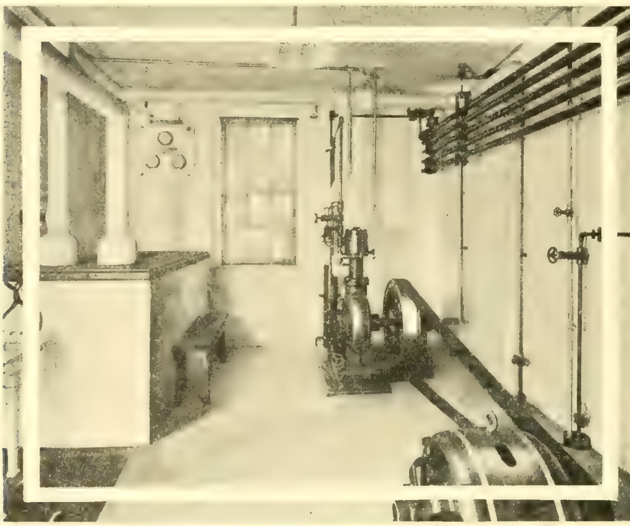


FIG. 48.—BRUNSWICK-KROESCHELL RESIDENCE INSTALLATION, INCLUDING ICE-MAKING SET.

Fig. 48 shows a typical residence installation including an ice-making set.

Carbondale.—Fig. 49 shows a self-contained unit made by the Carbondale Machine Company, Carbondale, Pa. Ammonia is the refrigerant used.

The compressor is of the vertical, single-acting type. Worthington feather valves are used in the compressor. The cylinder is ground and honed to size. All the bearings are of the die cast type and are interchangeable.

The condenser is of the horizontal, tubular type with removable heads and straight tubes, making it conveniently cleaned and inspected. The water passes through seamless drawn steel tubes, which are expanded into forge welded heads.

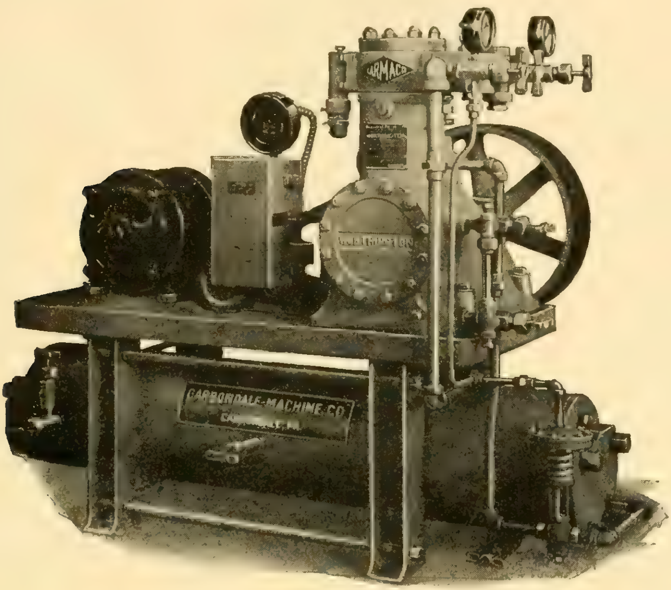


FIG. 49.—CARBONDALE REFRIGERATING UNIT.

The one ton unit is driven by a three horse power motor at 265 r.p.m. when operated at standard suction and discharge pressures. The same machine is rated at two tons when operated at 530 r.p.m. by a five hp. motor. This machine has a vertical compressor of 3½ inch diameter and 3½ inch stroke.

The unit is equipped with the following automatic devices:

Automatic starting panel.
High pressure cut out switch.
Ammonia pressure water control valve.
Automatic expansion valve, with strainer.

The high pressure cut out is arranged with hand reset, so that in case it acts, the machine will not start itself until the

cause for the high ammonia pressure is determined and corrected.

The thermostat operates at full voltage and is fitted for two connecting wires. The thermostat is very accurate, and with a properly designed room, or box, the temperature may be held within a few degrees of the desired temperature.

The water regulating valve is mounted on the front end of the condenser. It is of the pressure actuated type and controls the flow of water by the ammonia pressure of the condenser. When the ammonia pressure drops, the flow of water ceases; and as it rises, the flow is increased, thus obtaining maximum economy in the use of water.

The ammonia connections, both to this valve and to the high pressure cut out, are short and protected by other parts of this unit. Valves are provided in both connections, so that the appliance can be removed for repairs or adjustment.

The automatic expansion valve is of the spring and diaphram controlled type, selected for the service that it has given hundreds of users, and of a type that will operate satisfactorily under the most adverse conditions.

Champion.—The Champion Electric Icer is made by the Champion Electric Company of St. Louis, Missouri, a division of the Champion Shoe Machinery Company.

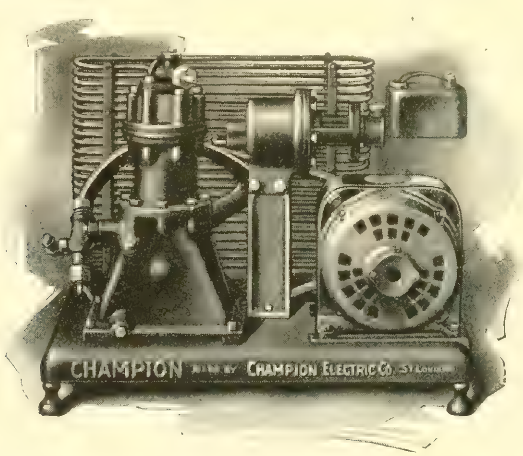


FIG. 56.—"JUNIOR" MODEL, CHAMPION ELECTRIC ICER.

Fig. 50 shows the Junior Model. This compressor is of the single cylinder reciprocating type. A belt drive is used.

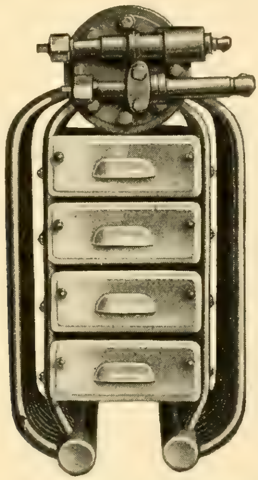


FIG. 51.—CHAMPION COOLING UNIT.

The cylinder block is lined with tool steel bushing hardened and ground. The pistons are semi-steel equipped with two piston rings. The crankshaft is drop forged in one piece.

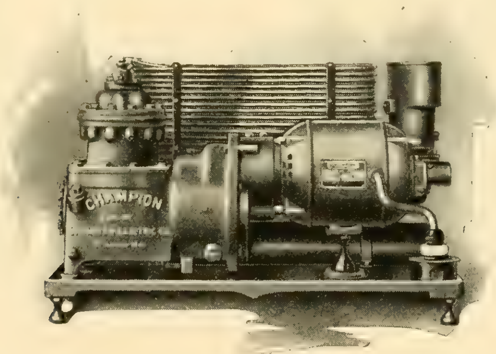


FIG. 52.—"SENIOR" MODEL, CHAMPION ELECTRIC ICER.

Large eccentric bearings are used which are of semi-steel. Model No. 6 Junior Compressor has 1½ inch diameter cylinder, 1⅙ inch stroke, and operates at 500 r.p.m. Model No. 8

Junior compressor has 1½ inch diameter cylinder, 1½ inch stroke, and operates at 500 r.p.m.

The condenser consists of a double coil of ¼ inch copper tubing. Natural air circulation is used for cooling the condenser.

FIG. 53.—CHAMPION "SENIOR" MODEL WITH COOLING UNIT INSTALLED.

The automatic control is of the adjustable pressure type on the suction line.

The motor is 1/6 hp. and is of the induction-repulsion type.

Fig. 51 shows the cooling unit which operates on the

flooded system. This uses direct expansion in open type coils. The refrigerant is sulphur dioxide.

Fig. 52 shows the Senior Model which consists of a two-cylinder reciprocating type compressor geardriven. The ¼ hp. motor drives the compressor by means of completely enclosed gears. The gear drive consists of a composition pinion on the motor shaft, driving a helical cut semi-steel gear on crank shaft. All moving parts are enclosed and run in oil. The compressor has a 1½ inch bore, $1\frac{1}{16}$ inch stroke, and operates at 500 r.p.m.

The condenser, automatic control and cooling units are similar in type to those used on the Junior Model.

Fig. 53 shows the Senior Model and cooling unit complete with the cabinet.

Chilrite.—This machine, Fig. 54 is made by the Narragansett Machine Company in Pawtucket, R. I.

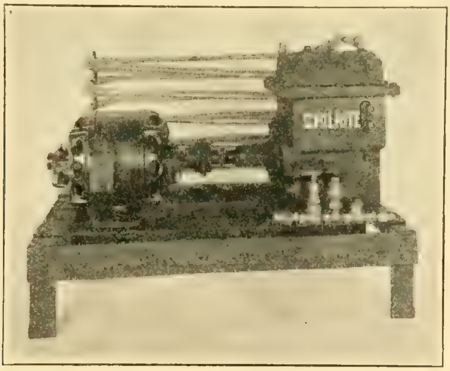


FIG. 54.—CHILRITE REFRIGERATING UNIT.

The compressor is of the multi-stage rotary gear type and uses sulphur dioxide as the refrigerant. The condenser consists of a coil of finned tubing.

The cooling unit is of the dry system consisting of a coil connected with an expansion valve and submerged in a tinned copper tank filled with alcohol and water. In some installations the tank is dispensed with and the open coil system is used.

The temperature is controlled by an immersion type of thermostat of the tilting tube variety.

The machine is made in three sizes using 1/6, 1/4 and 1/3 hp. motors and is adapted to operate with any standard make of cabinet.

Climax.—Fig. 55 shows the self-contained refrigerating unit manufactured by the Climax Engineering Company of Clinton, Iowa. The refrigerant used is methyl chloride.

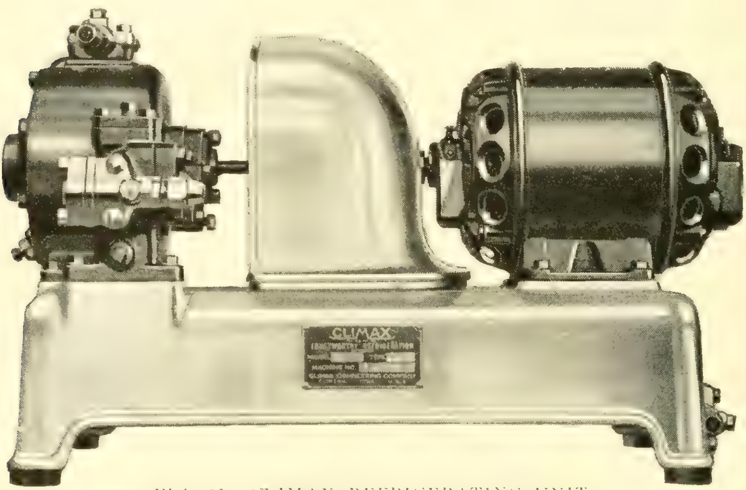


FIG. 55. CLIMAX REFRIGERATING UNIT.

The condenser, compressor and motor are all mounted on the same base. The compressor is direct connected to the electric motor. A rotary type of compressor is used, consisting of only three moving parts. The rotating element operates on bronze bearings submerged in oil, thus providing positive lubrication.

The refrigerating unit is made in four different sizes:

Model	Motor	Weight	Ice Melting Effect
Model G	1/8 hp.	86 lbs.	75 lbs.
Model F	1/4 hp.	127 lbs.	150 lbs.
Model E	1/3 hp.	204 lbs.	300 lbs.
Model D	1/2 hp.	224 lbs.	500 lbs.

The condenser is of the radiator type and is mounted under the base. The air is drawn through the radiator and does dou-

ble duty by being blown against the compressor case. A float valve is used for the liquid control.

The operation of this unit is controlled by a thermostat or pressure control and is entirely automatic.

Coldmaker.—In Fig. 56 is illustrated the Coldmaker household refrigerating machine manufactured in Toledo, Ohio. The machine is installed in the basement or other out of the way place and the cooling coils are installed in the ice compartment of any box.

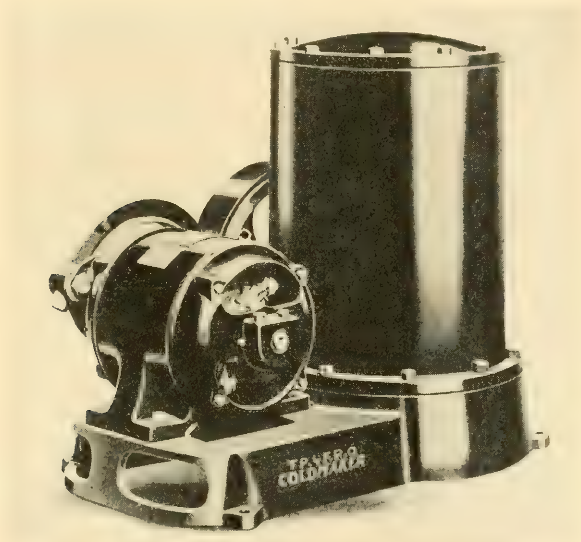


FIG. 56.—COLDMAKER REFRIGERATING MACHINE.

Coldmaker consists of a water cooled ammonia system of automatic refrigeration. The compressor is motor driven by means of a flat leather belt.

The compressor has two cylinders, 1¼ inches in diameter by 1¼ inch stroke made of a semi-steel casting. Suction port openings are located near the center of the cylinders.

The pistons have long ports on each side to admit the suction gas. The suction valve is located in the upper end of the piston. The top end of the piston has four piston rings

and the lower end three rings. The wrist pins are made of nickel steel. The eccentrics are made of gray iron castings and are cast integral at an angle of 180°. They are shrunk and pinned to the shaft. The shaft is made of forged steel and is ground to size after the eccentrics have been shrunk on.

The discharge valves are made of nickel steel, light in weight, and cup shaped. They give full area opening of the cylinder and permit the compressor to handle saturated gas or liquid without endangering the safety of the machine.

The suction valves, located in the head of the pistons, are made of nickel steel. They have a large suction area and operate with a minimum lift.

Both suction and discharge valves are provided with springs to hold the valves snugly to seats when the pressure is released.

The end plates containing the shaft bearings are made of semi-steel, bored and reamed accurately, and fitted with die cast bearings.

The stuffing box is provided with an oil gland, or ring, with soft packing on both sides. The gland has a direct connection with an oil reservoir, entirely separate from the oil in the crank case. This in reality, forms an oil storage in the center of the stuffing box, which keeps the packing soft and resilient, and effectively seals the stuffing box so that no gas can get past this oil seal. A threaded packing nut or gland forms the outer end of the stuffing box proper.

The rings are made of soft, close grained gray iron. Each ring is cast individually and the inner surface is left unfinished to give toughness and resiliency to the ring. The rings are cast eccentric.

The cylinder heads are made of semi-steel. The discharge port is located in the cylinder head. The water jacket surrounds the compressor, condenser and liquid receiver. Any leak which might occur will be absorbed by the water. The condenser is made of extra heavy ½ inch steel pipe bent to shape and surrounding the compressor cylinders.

Some advantages of the water jacket surrounding the compressor, condenser and liquid receiver are:

1. It absolutely assures splendid operating conditions for the compressor, preventing any contraction or expansion of the metals.

2. It prevents the oil from vaporizing in the crank case.

3. The bearings are kept at a uniform temperature and prevented from overheating.

4. It keeps the stuffing box in excellent condition at all times.

5. It gives additional condensing surface on the receiver.

6. Provides a direct outlet to the sewer in case of leaks.

The expansion valve is of the diaphram pressure type. It is screened to prevent dirt and scale from getting to the valve seat.

The automatic control consists of a small 1/50 hp. motor which is reduced in speed by worm gears. One of these is directly connected to a rotating shaft, which contains on one end the rotary switch with three terminals corresponding to the three terminals on the thermostat, and the two terminals for the power motor switch. On the one end is fixed the water cock for regulating the flow of water to the condenser shell. As both switches and water valve are firmly fastened to the same shaft and rotate at the same time, it is plainly evident that both water and current must be on or off at the same time.

If the water supply fails, a diaphram pressure switch directly connected to the water line cuts off the motor instantly. If the pressure falls below a safe margin, the motor will not start again until the water pressure has been again restored to normal.

With alternating-current, a repulsion-induction motor is used, continuous duty type. With direct current, a compound wound continuous duty motor must be used. The size furnished is ⅓ horse power, 1200 r.p.m.

The capacity of the Coldmaker with the usual allowances for compressor inefficiencies, plus an additional allowance because of the small size of the equipment, figures out approximately 279 pounds of refrigeration when operating 24 hours. The machine is rated at 250 pounds of refrigeration.

Cooke Refrigerating Machine.—The Cooke Household Refrigerating Machine is manufactured by Mr. George J. Cooke, Sr., of Chicago, Illinois.

The compressor is of the single cylinder, vertical, single-acting type. A cross-section and longitudinal section is shown in Fig. 57. The cylinder diameter is 1½ inches and the stroke is 1½ inches. The compressor operates at 450 r.p.m. normally. The suction valve is of the port type; the discharge valve is of the disc plate type. The compressor crank shaft and

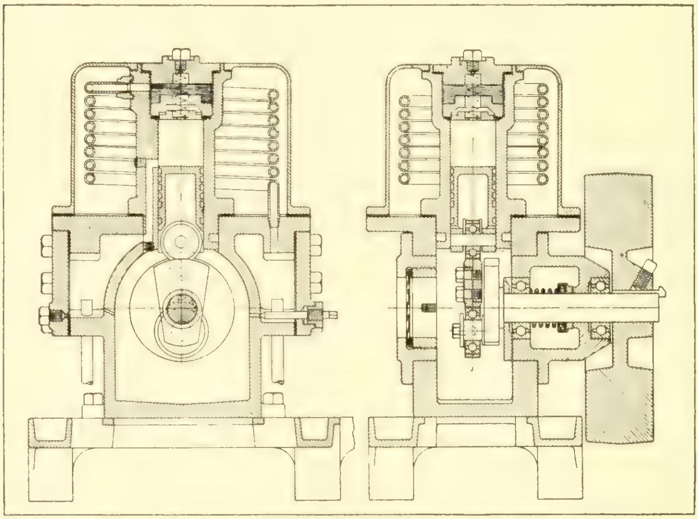


FIG. 57.—SECTIONAL VIEW OF COOKE REFRIGERATING MACHINE.

connecting rod are provided with ball bearings to reduce the friction losses to a minimum. The crank shaft is packed by means of the patented seal ring. The packing is submerged in oil while the machine is in operation. A small but heavy flywheel is keyed to the crankshaft. A glass-covered observation port is provided opposite the end of the crank shaft for observing the condition of the lubricating oil.

The condenser consists of a spiral pipe coil around the compressor cylinder, as shown by Fig. 57. An exterior casing encloses the water circulation for the condenser and water jacket for the compressor cylinder. The ammonia gas is **discharged**

into the top of the spiral condenser coil and the liquefied ammonia drains out of the bottom of the coil into a combined ammonia receiver and oil trap which is cast integral with the compressor frame. An automatic oil return valve is used.

The compressor is driven by means of a ¼ hp. electric motor running at 1,750 r.p.m. It is belted to the compressor by a "V" type belt. Proper belt tension is obtained by mounting the motor upon a hinged base. The compressor and motor are mounted upon a substantial cast-iron base. The compressor and motor unit is 20 inches long, 10 inches wide, and 15 inches high overall and weighs 150 pounds.

The cooling element consists of a brine tank containing direct expansion coils. Trays are provided for the freezing of seventy-two 1½ inch ice cubes for table use. The expansion valve is of the angle standard orifice type, protected from foreign matter by a small strainer in the liquid line just ahead of the valve. It is located just above the brine tank.

The machine is self-contained, simple in construction, and all parts are readily accessible. The operation of the machine is positively and automatically controlled by means of a mercoid electric switch which is actuated by a thermostatic element submerged in the brine of the main tank. The controls may be adjusted to maintain any reasonable temperature in the refrigerator. The condenser water supply is controlled by a diaphram valve which is actuated by the condenser pressure.

The total charge of the ammonia in the system is said to be 3½ ounces. The capacity of the machine, it is claimed, is 350 pounds of ice melting effect per day. It may be installed on or adjacent to any refrigerator having a maximum of 35 cubic feet.

The refrigerating machine has in connection with it an ice cream freezer of the domestic size. This is mounted on the side of the refrigerator. The ice cream freezer has a brine tank containing a submerged spiral direct expansion coil. Operation of the freezer requires only a one-quarter turn of a hand lever located just above the main brine tank. It is claimed that one gallon of ice cream may be frozen in ten to fifteen minutes.

Copeland. Fig. 58 shows the household refrigerating machine made by Copeland Products, Incorporated, of Detroit, Michigan.

The compressor has one cylinder and is of the single-acting reciprocating piston type. The motor is 1/6 hp. and drives the compressor by means of the "V" type belt.

The refrigerant used is Freezol or Iso-Butane, a hydrocarbon gas which is odorless, non-corrosive and non-poisonous.

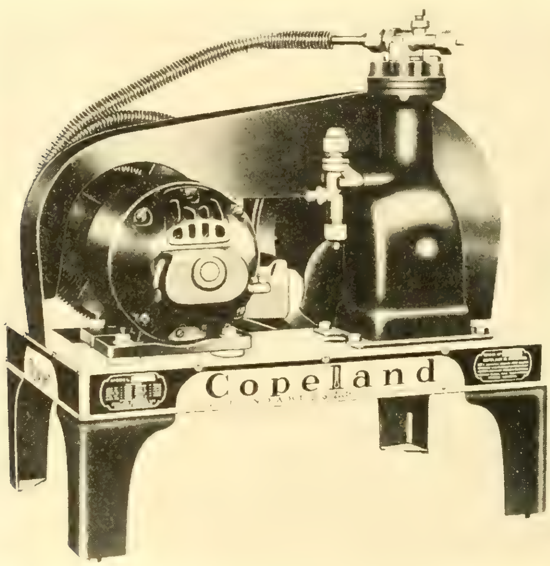


FIG. 58.—COPELAND REFRIGERATING UNIT.

The condenser is made of thin copper tubing and is cooled by forced air obtained by means of a fan attached to the motor shaft.

The cooling units are made entirely of copper and brass. Copper tubing is used for the expansion coils. This tubing encircles the ice tray sleeves, thus reducing the time required to freeze water or desserts. Cooling units are made in various sizes suitable for different sizes and types of refrigerating cabinets.

The expansion valve, Fig. 59, is located on top of the cooling unit and is of the balanced type using a diaphragm

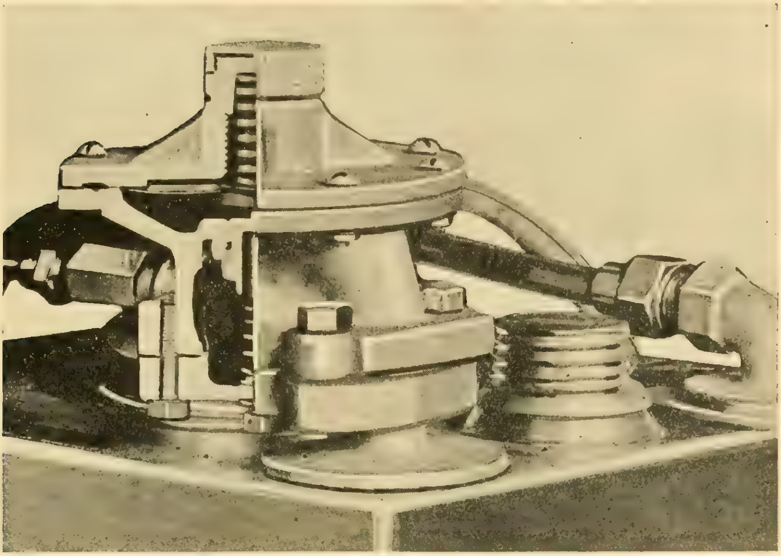


FIG. 59.—COPELAND EXPANSION VALVE.

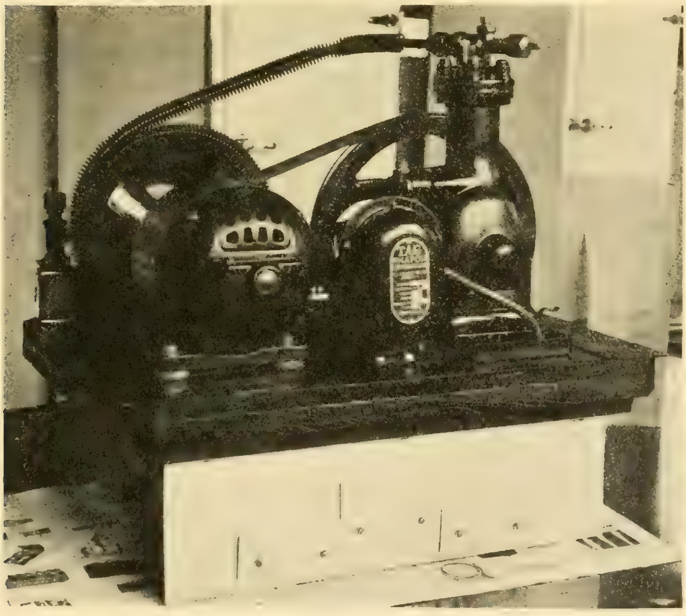


FIG. 60.—COPELAND ONE-PIECE FREEZING UNIT AND MACHINE.

between the outside adjusting spring and the regulating needle inside the valve.

The temperature control is automatic and is obtained by means of a thermostat responsive to the cooling unit temperature.

A line of all-metal cabinets is supplied.

Fig. 60 shows the freezing unit and machine all in one piece, mounted on an insulated base which forms the top of the refrigerator. This unit sets down into the top of the refrigerator, resting on an insulated base, and forms an air-tight seal with its own weight.

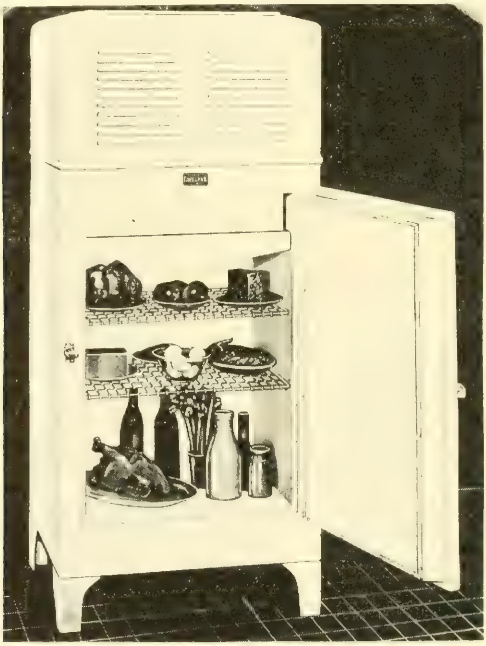


FIG. 61.—COPELAND CABINET AND REMOVABLE UNIT.

Fig. 61 shows the cabinet in which the removable unit operates. This cabinet is 62½ inches high, 26¼ inches wide and 21 inches deep.

The exterior is covered with steel and the walls are insulated with 1½ and 2 inches of solid cork. The exterior is of steel finished in white pyroxylin.

The cooling unit has an ice capacity of 6.6 pounds and a capacity of 108 cubes at one freezing. The food space is 5¾ cubic feet and the shelf area is 8 square feet.

CP Refrigerating Machine.—Fig. 62 shows the self-contained refrigerating machine made by the Creamery Package Manufacturing Company, Chicago, Illinois.

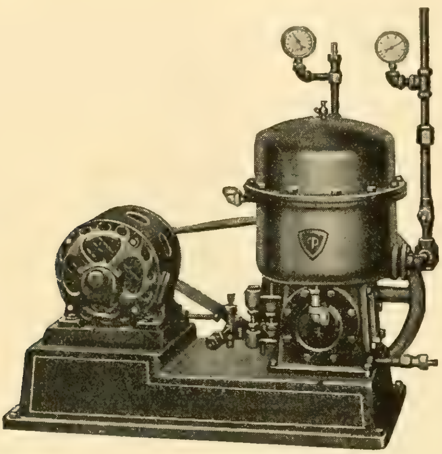


FIG. 62.—CREAMERY PACKAGE REFRIGERATING MACHINE.

The refrigerant used is ammonia. The compressor, liquid receiver, condenser, necessary valves, oil gauge and strainer are all mounted on one base. The compressor is of twin cylinder construction. The compressor has adjustable crank pin bearings, drop forged connecting rods and crankshafts, and improved type valves which are easily removable.

A ½ hp. motor is used to drive the compressor. This machine has a capacity of ¼ ton refrigeration per day.

The machine is entirely automatic in operation. A thermostat is used to maintain any desired temperature.

Delphos.—Fig. 63 shows the complete self-contained refrigerating unit made by the Delphos Ice Machine Company, at Delphos, Ohio.

Ammonia is the refrigerant used. This unit consists of a complete high-side including a compressor, scale trap with

relief valve, oil trap, condenser, receiver, low and high pressure gauges, gauge and purge valves and electric motor. A cast iron base is used.

The compressor is of the enclosed crankcase type and all of the moving parts and bearings are lubricated by the splash of the eccentrics passing through the oil contained in the reservoir at the bottom.

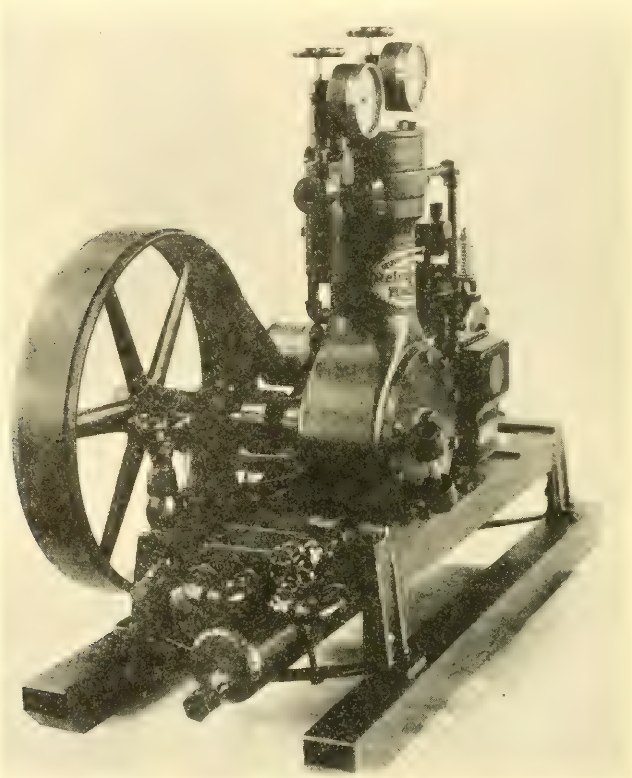


FIG. 63.—DELPHOS REFRIGERATING UNIT.

All the compressors are two cylinder with the exception of the three-fourths ton size which is single cylinder.

The ammonia condenser is of the double pipe, counter-current type with all ammonia joints welded. The water pipes are connected by means of return bends and lip unions to permit ready access for cleaning and removing water sedi-

ment. This can be done without disturbing the ammonia. The condenser is made up of black steel pipe with steel heads securely welded. The condenser and receiver are mounted integral with shut-off valve placed between condenser and receiver.

Electrical Refrigerating Co.—Fig. 64 shows a cross-section view of the compressor used in the machine manufactured by

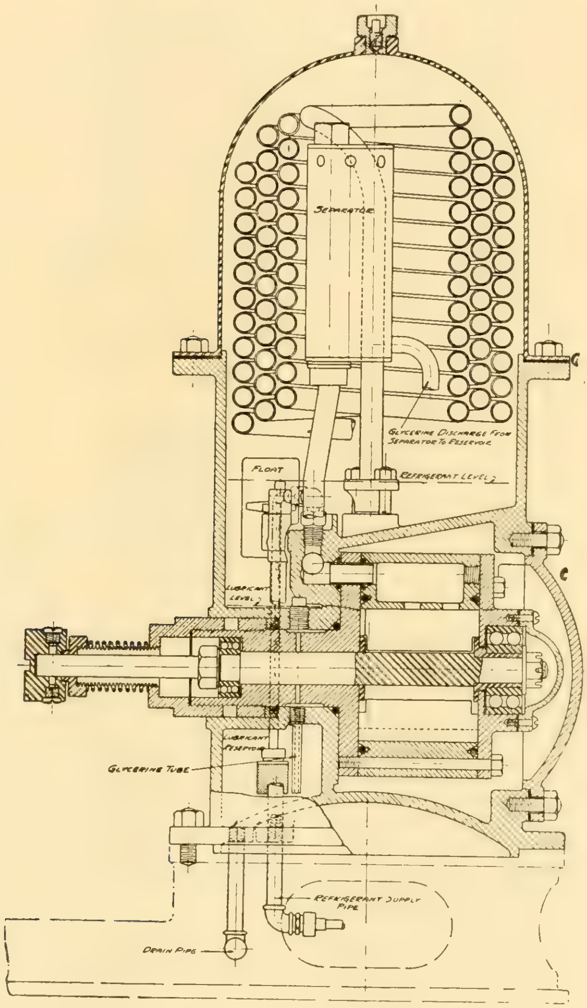


FIG. 64.—WILLIAMS REFRIGERATING MACHINE.

the Electrical Refrigerating Company at Brooklyn, New York.

This is a water-cooled type using ethyl chloride as the refrigerant. The flow of the refrigerant is controlled by means of a float valve.

Four sizes of this machine were developed including ¼, ½, 1 and 2 hp. Most of the parts of all these sizes are interchangeable in the same housing, the outside diameter of all compressors being the same while the variations in their capacity is obtained by changing the bore and depth dimensions.

The capacity of the larger size condenser is provided by increasing the height of the dome.

ElectrICE.—Fig 65 shows the top view of the rotary compressor used on the household refrigerating machine made by the American ElectrICE Corporation at Belding, Michigan.

FIG. 65.—TOP VIEW OF ELECTRICE ROTARY COMPRESSOR.

The compressor is of the rotary type, using one set of gears operated at motor speed. The motor is direct connected to the compressor, eliminating the use of belts.

The compressor consists of two coils of thin tubing cooled by forced air obtained by means of a fan mounted on a motor shaft. The refrigerant control valve is mounted on the compressor base.

The motor control is responsive to a mercoid thermostat, starting and stopping the compressor, and is necessary to maintain a constant temperature in the refrigerator.

The ice-melting capacity of this unit is 125 pounds per twenty-four hours at 85° F. temperature.

Electro-Kold.—Figs. 66 and 67 show compressor units made by the Electro-Kold Corporation of Spokane, Wash. Compressor units are made in three sizes.

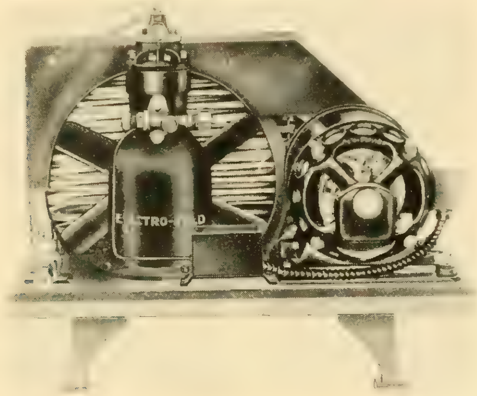


FIG. 66.—ELECTRO-KOLD COMPRESSOR UNIT.

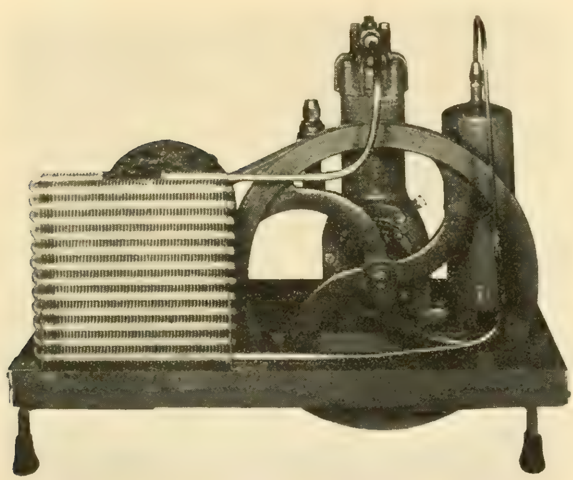


FIG. 67.—ELECTRO-KOLD COMPRESSOR UNIT.

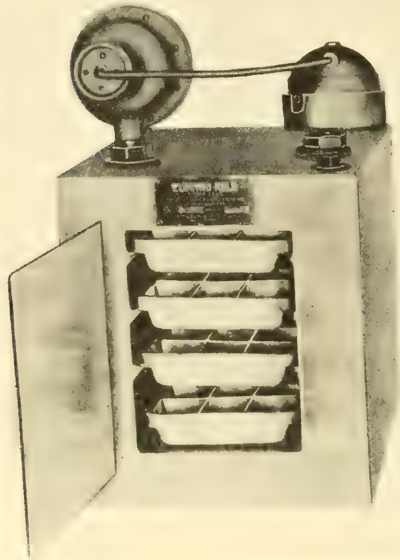


FIG. 68.—ELECTRO-KOLD FROST TANK.

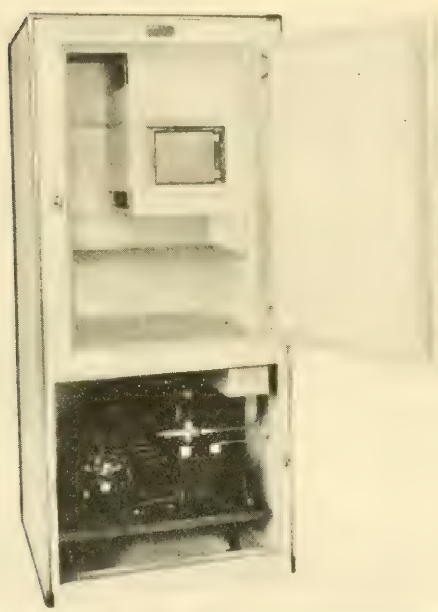


FIG. 69.—COMPLETE ELECTRO-KOLD SELF-CONTAINED UNIT.

The refrigerating capacity and size of motors are as follows:

Type	Size Motor	Number Cylinder	Refrigerating Capacity
C	¼ hp.	1	10 cu. ft.
F	½ hp.	1	40 cu. ft.
A	½ hp.		60 cu. ft.

Sulphur dioxide is the refrigerant used.

The condenser consists of copper tubing and it is cooled by forced air.

A pressure control is used instead of a thermostat to regulate the operation of the machines.

Fig. 68 is a view of a typical frost tank with a capacity for cooling ten cubic feet of food space. It has four ice trays of eighteen cubes each.

Fig. 69 shows a complete self-contained unit. The exterior is of steel with Duco finish. The insulation is of 1½ inch corkboard. Several other larger self-contained models are produced.

Everite.—The Everite Products, Inc., Dayton, Ohio, manufactures the motor driven air cooled refrigerating machine, Fig. 70.

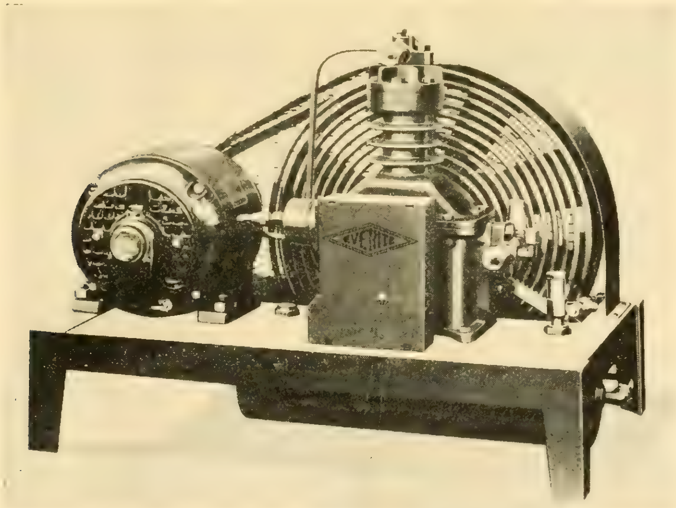


FIG. 70.—EVERITE REFRIGERATING MACHINE.

This machine may be used in the standard home refrigerator or in special all-steel, porcelain lined refrigerator cabinets furnished in five sizes from seven to twenty cubic feet food storage capacity.

Both single and double cylinder compressors operated by $\frac{1}{6}$ and $\frac{1}{4}$ hp. motors are manufactured. These have refrigerating capacity of twelve to twenty-five cubic feet respectively.

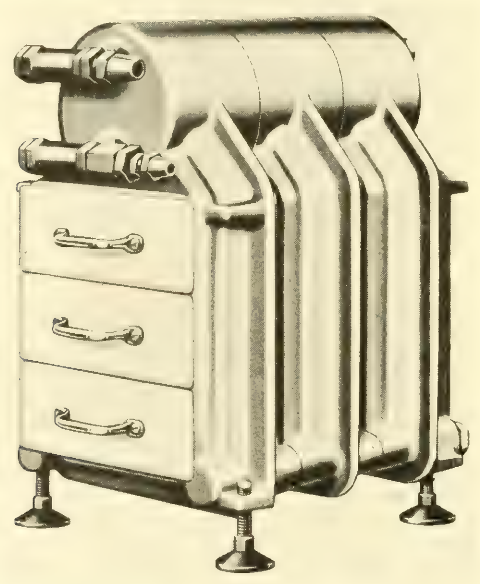


FIG. 71.—EVERITE FLOODED TYPE COOLING UNIT.

Commercial systems are also manufactured in $\frac{1}{4}$ and $\frac{1}{2}$ ton sizes.

Sulphur dioxide is the refrigerant used.

The Everite cooling unit, Fig. 71 is of the flooded type employing a float valve in its header. These are of cast construction built up in sections similar to a radiator which provides maximum cooling surface and permits the building up of suitable size cooling units for various size refrigerators from

the smallest to the largest within the capacity of the compressors.

The outstanding feature in this system is the condenser which is mounted directly in front of and covering the entire area of the fan pulley thus causing all the air drawn in by the fan to pass through the condenser rendering it very efficient and permitting neat and compact construction.

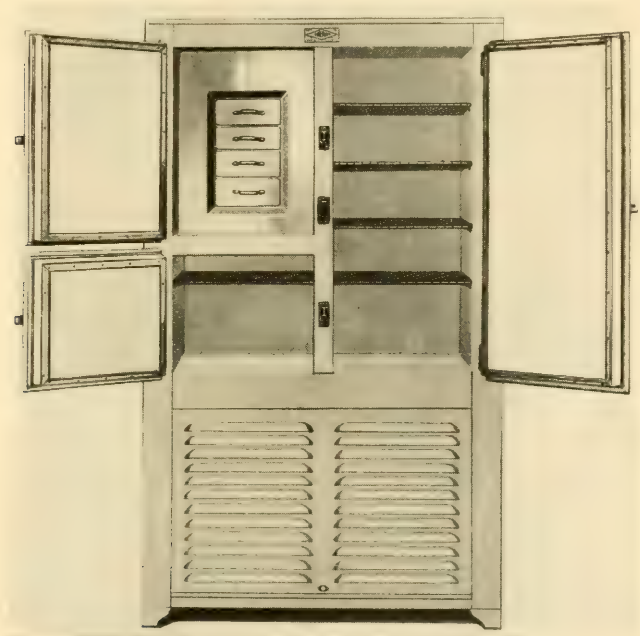


FIG. 72.—ALL-STEEL CABINET WITH EVERITE UNIT.

The control is the pressure type (no thermostat is used) thus eliminating difficulties usually experienced in this type of control.

Fig. 72 shows one of the all-steel cabinets supplied as a self-contained unit.

Frigidaire.—Two general types of Frigidaire household and commercial refrigerating machines are made by the Delco-Light Company at Dayton, Ohio. These are air-cooled and water-cooled units using sulphur dioxide as the refrigerant.

Fig. 73 shows the model "G" air-cooled condensing unit comprising the compressor, condenser, receiver, motor and automatic control, mounted on a steel base. The compressor

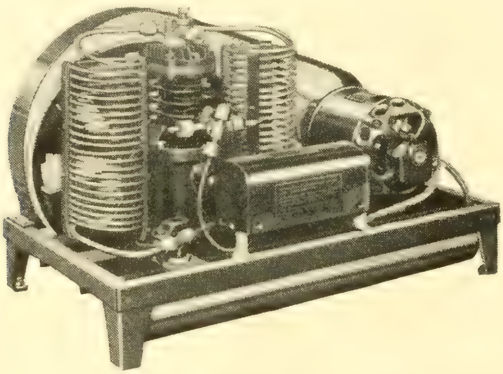


FIG. 73.—FRIGIDAIRE MODEL "G" AIR-COOLED UNIT.

is a two cylinder, vertical, single-acting type. The discharge valve is of the flapper valve construction. A disc suction valve is used in the top of the piston. An eccentric keyed to the shaft drives the pistons by means of the eccentric rods.

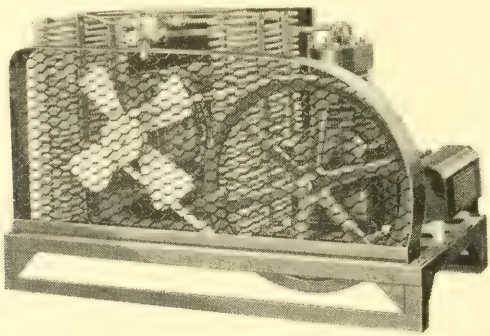


FIG. 74.—LARGER SIZE FRIGIDAIRE AIR-COOLED COMPRESSOR.

The compressor shaft is sealed by a special metal ring which automatically compensates for wear. The compressor pulley contains fan blades which force air over the copper condenser coils located on opposite sides of the compressor. The condenser coils are made of flattened copper tubing. The ¼ hp.

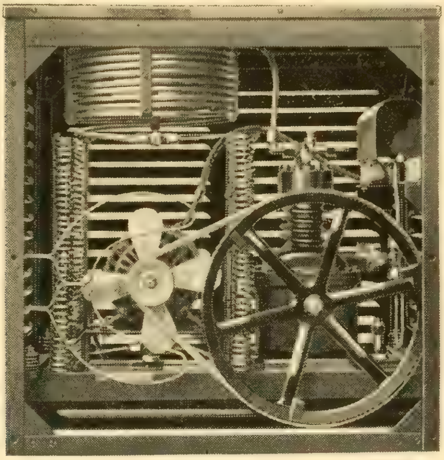


FIG. 75.—FRIGIDAIRE AIR-COOLED COMPRESSOR FOR HOUSEHOLD AND COMMERCIAL INSTALLATIONS.

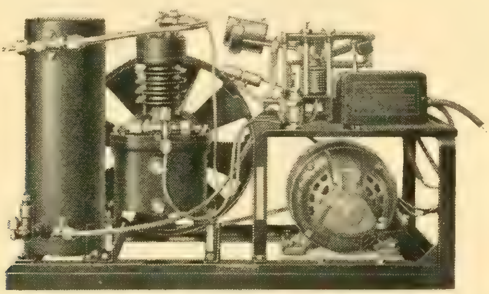


FIG. 76.—FRIGIDAIRE WATER-COOLED CONDENSING UNIT FOR COMMERCIAL INSTALLATION.

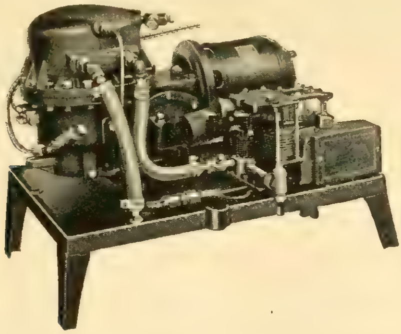


FIG. 77.—FRIGIDAIRE WATER-COOLED CONDENSING UNIT FOR COMMERCIAL INSTALLATION.

motor drives the compressor by means of a "V" type belt. The automatic control switch is actuated by a change of pressure on the low side of the refrigerating system.

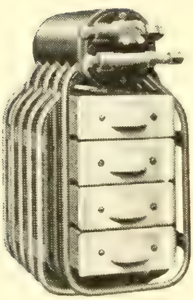


FIG. 78.—TYPICAL FRIGIDAIRE COOLING UNIT, FLOODED PRINCIPLE.

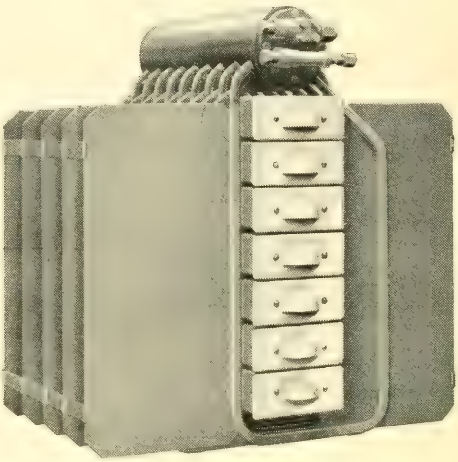


FIG. 79.—TYPICAL FRIGIDAIRE COMMERCIAL SIZE COOLING COIL, COPPER FINS.

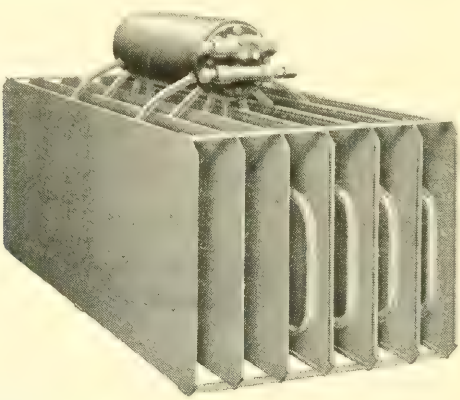


FIG. 80.—TYPICAL FRIGIDAIRE COMMERCIAL SIZE COOLING COILS, COPPER FINS.

Figs. 74 and 75 show larger sizes of air-cooled compressors used on household and commercial installations.

Fig. 76 and 77 are water-cooled condensing units used mostly for commercial work.

Fig. 78 shows a typical cooling unit which operates on the flooded principle. The header contains a float valve which controls the supply of liquid refrigerant to the cooling unit. A series of copper coils terminate in the header. Copper

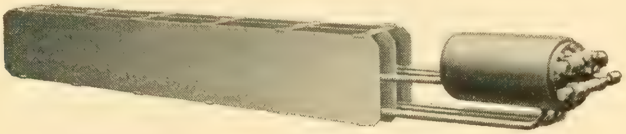


FIG. 81.—TYPICAL FRIGIDAIRE COMMERCIAL SIZE COOLING COILS, COPPER FINS.

sleeves are used inside the coils to accommodate the ice trays. This provides direct frost-coil cooling and the ice containers are of the self-sealing tray front type. Cooling coils are made

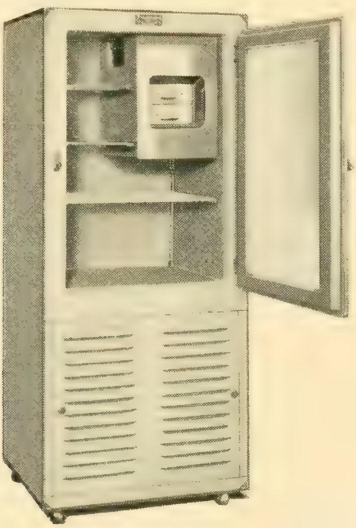


FIG. 82.—FRIGIDAIRE METAL CABINET.

in various sizes to fit in any household or commercial refrigerator.

Figs. 79, 80 and 81 show typical commercial size cooling coils with copper fins. The copper fins greatly increase the effective cooling surface. The copper tube is soldered to the fins and in some cases the copper tubes are flattened.

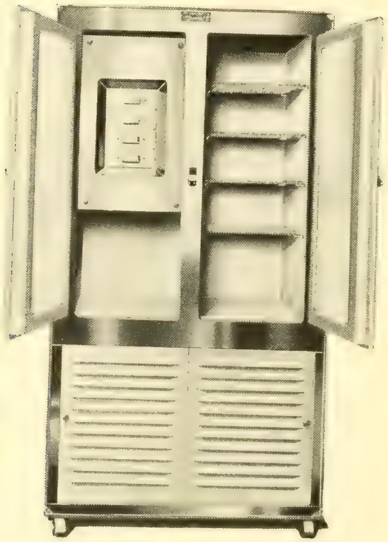


FIG. 83.—FRIGIDAIRE METAL CABINET.

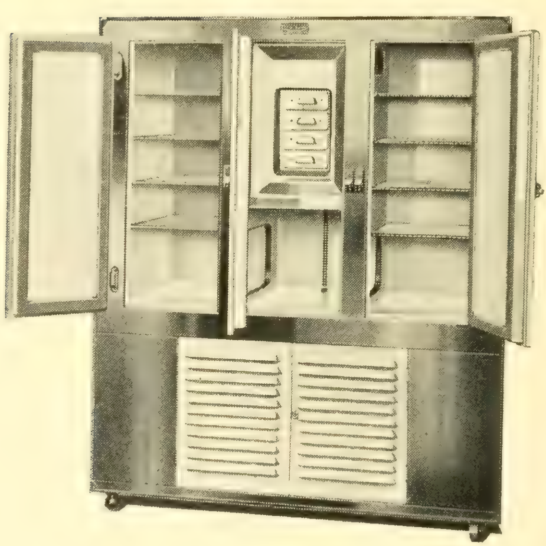


FIG. 84.—FRIGIDAIRE METAL CABINET.

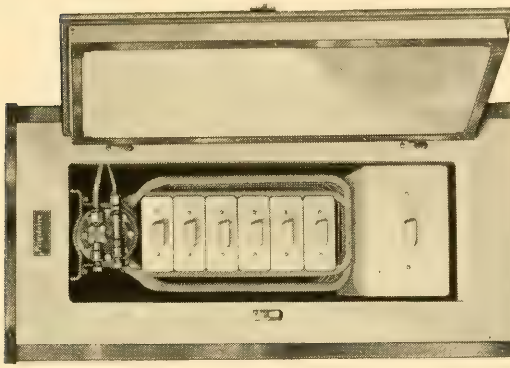


FIG. 85.—FRIGIDAIRE ICE MAKER.

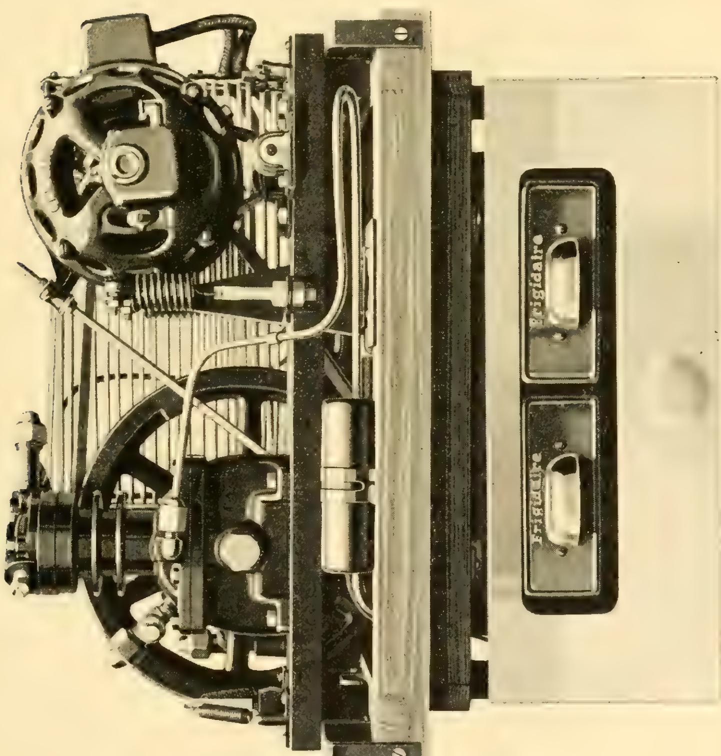


FIG. 86.—SPECIALLY DESIGNED FRIGIDAIRE MODEL

Figs. 82, 83 and 84 show typical metal cabinets. The refrigerating mechanism may be placed in the bottom of any of these cabinets. These are made with 5, 7, 9, 12 and 15 cubic feet of food compartment space. One line of cabinets is made with the exterior finished in white Duco on steel.

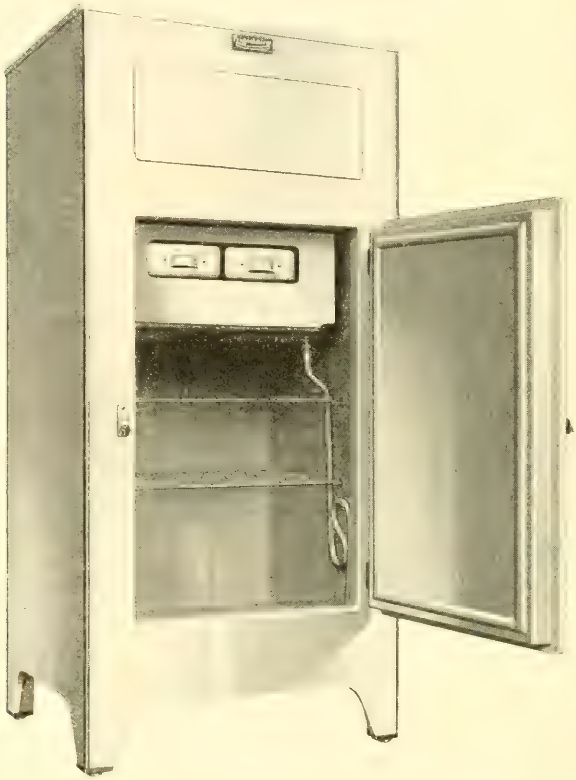


FIG. 87.—FRIGIDAIRE CABINET FOR SELF-CONTAINED UNIT.

Another complete line has the exterior of porcelain on steel, trimmed with monel metal. The front is of highly polished monel metal. These cabinets are insulated with corkboard and the linings, with the exception of one model, are made of porcelain on steel. The linings are of the one piece construction with rounded corners fitting flush above the door sills.

Fig. 85 shows the ice-maker which is used where a greater amount of ice is required than is provided by the cooling coil

installed in a regular refrigerator. The ice-maker contains six large capacity freezing trays and a storage compartment underneath.

Fig. 86 shows the specially designed model including the motor, compressor, condenser, and cooling coils arranged as a self-contained unit. A copper finned cooling coil is used. The compressor is mounted on a special spring suspension to eliminate vibration and afford quietness in operation.

Fig. 87 shows the cabinet in which the self-contained unit is used.

General Electric.—The General Electric Refrigerator is made by the General Electric Company of Schenectady, N. Y. Fig. 88 shows the complete refrigerating unit installed in a refrigerator cabinet.

The refrigerant used is sulphur dioxide. All moving parts are hermetically sealed in a drawn steel case containing the refrigerant—sulphur dioxide—and the lubricant. The condenser and evaporator coils are brazed to the steel casing. Specially developed insulated leads, similar to spark plugs, are used for the electrical connection to the motor. This construction permits complete enclosure and the elimination of the stuffing box through which gas or oil might leak. There is no external piping, cooling fan, belt or other external moving part.

The essential operating parts consist of:

1. A ⅙-hp., 110-volt, 60-cycle, split-phase motor mounted vertically. This motor is exceedingly simple in design and sturdy in construction—without brushes or other moving contacts.
2. A two-cylinder, single-acting compressor having oscilating cylinders.
3. A discharge valve of spring steel so arranged as to eliminate noise.
4. A copper tube condenser coil of circular cross section.
5. A float valve to regulate the amount of refrigerant passing to the evaporator coils.
6. An evaporator coil of copper tubing immersed in the brine tank.
7. An automatic regulating control.

The cooling tank, which is suspended within the cabinet itself, is covered inside and out with white, fused-on vitreous

porcelain—long wearing and easy to clean. The freezing trays, having a capacity of seven pounds of ice cubes, can be slipped into compartment in the tank. These trays are

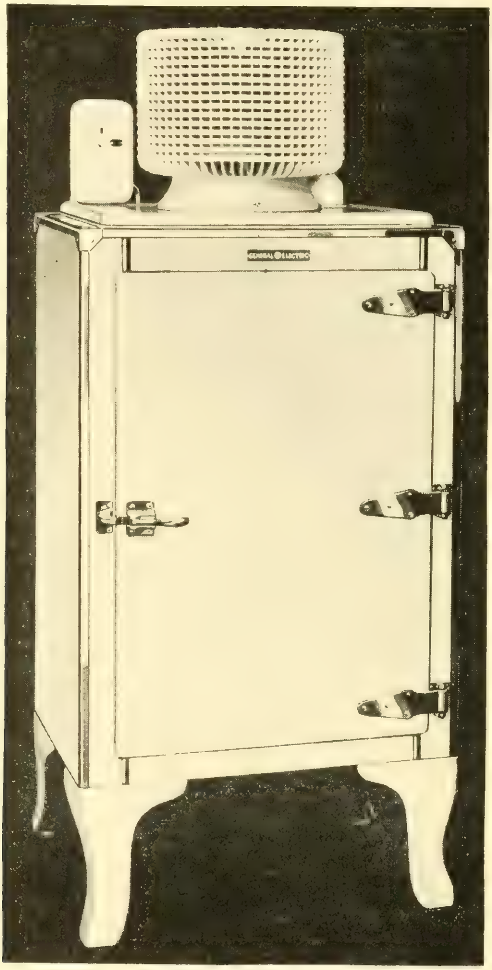


FIG. 88.—GENERAL ELECTRIC REFRIGERATOR.

of heavily tinned copper and are furnished with removable dividers to provide twenty-one cubes for each tray, or a total of sixty-three cubes for the three trays.

Complete automatic temperature and current control are provided. A control box on the front of the unit contains a manually-operated switch for disconnecting the machine, for defrosting or any other purpose.

The control box also contains an automatic thermostatic switch for starting and stopping the machine in response to temperature changes, a relay for transferring motor connections from starting to running position and a thermal, time-limit relay for protecting the motor from overload damage, also a reset button for a resumption of operation.

The automatic control is so adjusted that a brine temperature is maintained between 16° and 24° F., thereby maintaining a continuous cabinet temperature of from 40° to 50° F., which is admittedly the most satisfactory temperature for food preservation.

Installation is extremely simple as the refrigerator need only be moved to the desired position and attached to the nearest electric outlet. It can be installed wherever it will prove most convenient as there is no special plumbing or permanent fixtures to be connected to it. The cooling tank is placed in the cabinet, filled with a solution of salt brine and the refrigerating unit set into place. It is thoroughly portable and can readily be moved.

Fig. 88 shows the Model P-5-2 installed in a 5 cu. ft. refrigerator. This cabinet is of white porcelain exterior and interior. The exterior has flat polished metal trim strips. The exterior dimensions are height overall, 65¾ inches; width over hardware, 28⅜ inches; depth over hardware, 22⅞ inches. (Legs may be removed and the height reduced 11⅜ inches.)

The cooling unit contains one small tray for making ice cubes and one large tray for making cubes or frozen dessert. The total ice-making capacity is 56 cubes or approximately 7 pounds of ice. The food storage capacity is 5.37 cubic feet and the food shelf area is 7.9 square feet.

Hall Refrigerating Machine.—Fig. 89 shows the compressor of the ammonia machine manufactured by Thomas Hall & Son, Ltd., Rotherham, England.

The piston is of the truncated type and contains the suc-

tion valve. The discharge valve is of a special type. It is not affected by the heat of the compression. The valve is contained in a safety head which allows any liquid ammonia or oil to pass without damage.

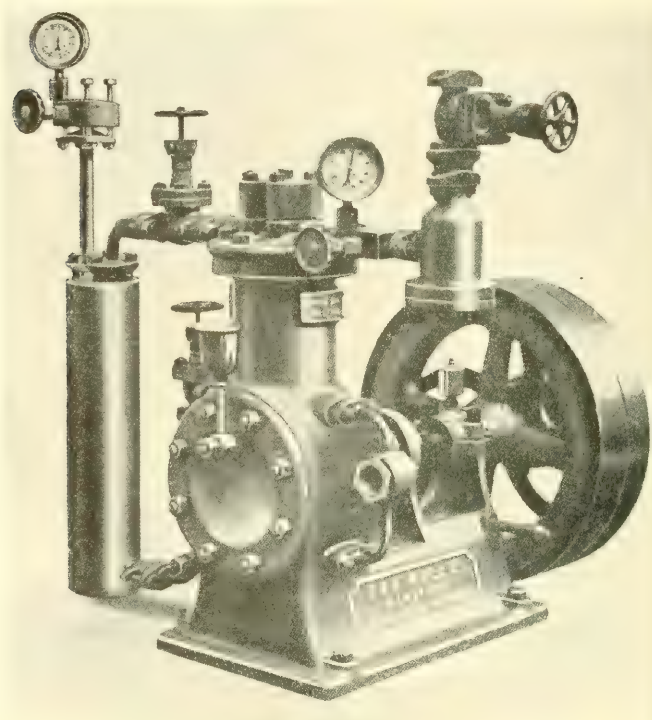


FIG. 89.—HALL REFRIGERATING MACHINE.

The crank case gland screws up like a nut, which prevents the gland from being pulled on one side and thus scoring the shaft. Metallic packing is used. The connecting rod is of forged steel. The dirt separator is fitted on the suction pipe, thus preventing any scale which may become loosened in the room coils from entering the machine and interfering with the working of the valves.

An oil sight glass is fitted in the end cover, which enables the level of the oil to be seen at a glance.

The stop valves are double seating, allowing the valves to be packed while the machine is running. The machine is fitted with a purge valve on the cylinder head to enable air and foul gases to be purged out of the system.

An oil trap is fitted on the discharge and is equipped with an oil return valve which enables the oil carried over through the valve, to be returned to the crank case, thus preventing it from going into the system.

A liquid ammonia receiver is fitted underneath the condenser making a compact unit.

The method of cooling usually adopted is by means of direct expansion coils immersed in a brine accumulator tank, which acts as a reservoir of cold and keeps the room down in temperature after the plant has been stopped. For some requirements air circulation is added. For frozen meat, direct-expansion coils are placed on the ceiling or on the walls.

This small size machine is capable of cooling a properly insulated cold room of 400 to 500 cubic feet to a temperature of 35° to 38° F.

Ice Maid.—The household refrigerating unit, Fig. 90, is made by the Lamson Company, Inc., at Syracuse, New York.

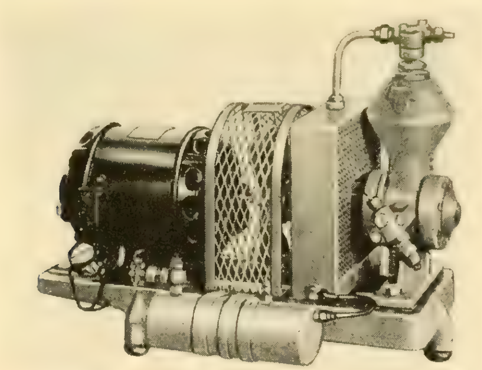


FIG. 90.—ICE MAID HOUSEHOLD REFRIGERATING UNIT.

The compressor is a direct connected rotary type running at motor speed and using ethyl chloride as a refrigerant. The compressor has a 2-bladed rotor mounted eccentric to the bore and is carried on annular ball bearings. The stuffing

box is of the sylphon bellows type, the bellows revolving with the shaft thereby carrying away any heat that may be generated by the seal.

The discharge valve is of the flapper valve type and consists of two flat steel discs riveted to the seat on one side. An efficient oil separator is an integral part of the oil reservoir, it is located in the dome of the pump and oil is fed by the pressure of the gas through holes drilled in the pump casting to the bearings and the rotor. This gives the effect of a full pressure system and is fully automatic, as the load on the pump increases the quantity of oil fed to the bearing also is increased. Oil is used as a lubricant increasing the efficiency of the pump considerably.

Suction and discharge shut-off valves are of the double-seated type permitting removal of pump without losing the charge of refrigerant. A check valve of the flat disc type is located on the suction side of the pump to obviate the possibility of oil running back into the suction line.

The compressor is driven through a flexible coupling of the fabric disc type which is self-aligning. Coupling and fan hub are integral.

The motor is of the induction repulsion type, both ⅓ and ¼ hp. being used. For remote control the motors run at 1750 r.p.m. and for self-contained installation they run at 1165 r.p.m. The motor is directly connected to the compressor by means of the fan and coupling assembly.

The condenser is of the Honeycomb Radiator type and has a cooling capacity equal to about 120 feet of ½-inch copper tubing. This is mounted between the pump and the fan. The fan running at motor speed throws a current of air directly through the radiator and thence around the pump. This direct positive cooling system is so effective that the machine usually operates under several pounds less head pressure than ordinary ethyl chloride systems using a copper tube condenser.

The compressor, radiator and motor are mounted as a unit on a rigid cast iron base. The base is drilled in such a manner that any standard motor that may be used can be mounted upon it readily. The base rides on sponge rubber balls which effectively absorb any slight noise or vibration.

Attached to the side of the base is a receiving tank of a capacity sufficient to hold the entire charge of refrigerant, thus making the entire condenser available for condensing purposes.

The dimensions of the entire unit are 24 inches long, 18 inches high and 12 inches wide. Due to this extreme compactness, the standard unit may be mounted in much less space than that occupied by the average machine and this can be installed in the base of a comparatively small refrigerator,

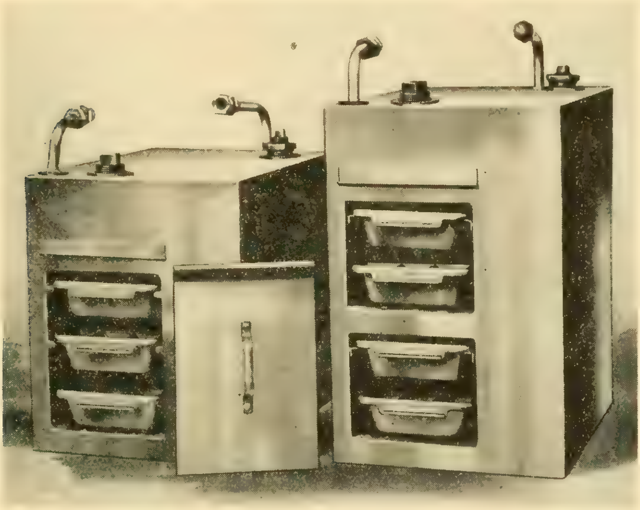


FIG. 91.—ICE MAID FREEZING UNIT.

without any changes whatsoever. The weight of the entire mechanical unit is approximately 100 pounds.

The freezing unit, Fig. 91, is of the brine tank type having a copper expansion coil of ell-shaped form and is equipped with compartment for ice trays. The tanks are nickel plated and are furnished in a variety of sizes sufficient to accommodate all standard refrigerators. The ice trays have a capacity of 24 cubes of ice.

The tray compartment is equipped with a cover which is so designed that it will not freeze to the tank and thus make it difficult to remove the ice tray.

The expansion valve is of the balanced type having only one spring which is the adjusting spring. It is constructed with a sylphon bellows and is fully automatic in its action. It is readily adjustable from the outside and is provided with an efficient means preventing moisture freezing and interfering with the operation of the bellows.

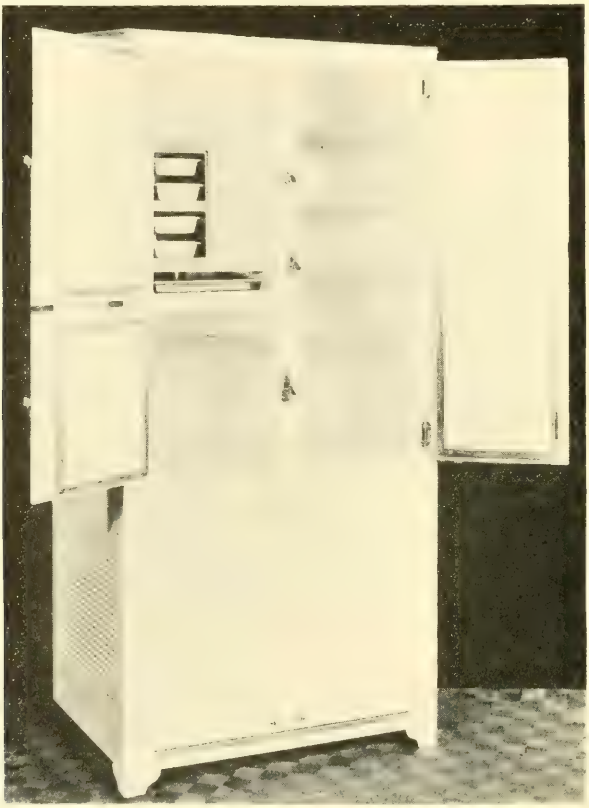


FIG. 92.—ONE OF THE TWELVE ICE MAID MODELS.

Control of the machine is effected by means of a mercoid switch located outside the refrigerator. It is connected to the refrigerator by means of a capillary tube which is attached to a bulb immersed in the brine, the other end of the tube being connected to a sylphon bellows actuating a tilting glass

tube containing mercury, which makes or breaks the circuit as the bulb is tilted back and forth. A brine temperature of 16° or 20° is maintained.

This method of control gives uniform brine temperature regardless of outside temperature. Only one size compressor is furnished, but by substitution of butane for ethyl chloride comparatively large restaurant, butcher boxes and other commercial applications can be handled.

A complete line of refrigerators with self-contained units are furnished in both wood and all metal comprising twelve different models from 5 to 20 cu. ft. food storage capacity. Fig. 92 shows one of these models.

Installation is simple as there are no electric wires entering the refrigerator and the standard mechanical unit is readily installed either as a remote or self-contained unit.

Iroquois.—Fig. 93 shows the compressor-condenser unit, made by the Iroquois Refrigeration Company, associate of the

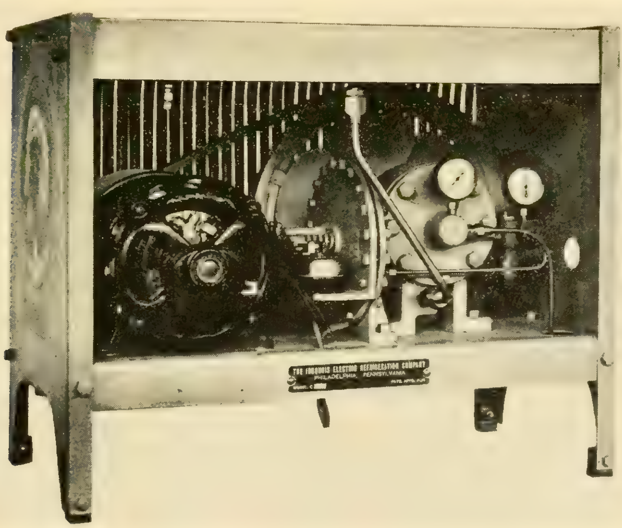


FIG. 93.—FRONT VIEW, IROQUOIS COMPRESSOR-CONDENSER UNIT.

Barber Asphalt Company of Philadelphia, Pennsylvania. Ethyl chloride is used as the refrigerant.

Fig. 94 shows the rotary type compressor used with this

unit. The condenser, Fig. 96, is of the double header type consisting of a series of copper tubes arranged so as to form a guard for the compressor. The condenser is cooled by two

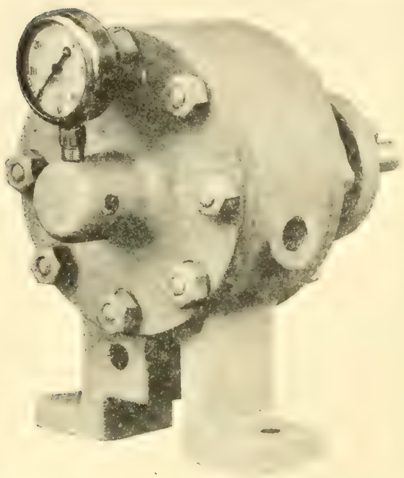


FIG. 94.—IROQUOIS ROTARY TYPE COMPRESSOR.

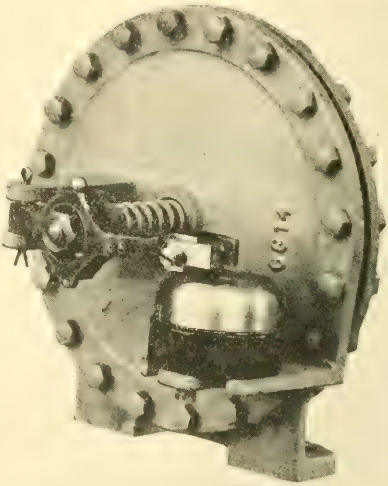


FIG. 95.—IROQUOIS PRESSURE CONTROLLED SWITCH.

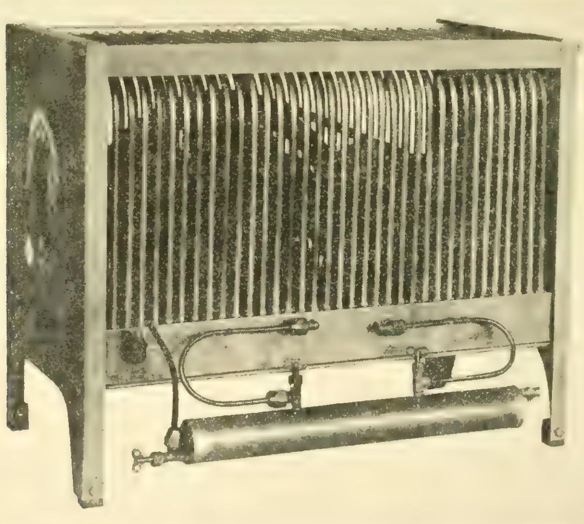


FIG. 96.—REAR VIEW, IROQUOIS COMPRESSOR-CONDENSER.

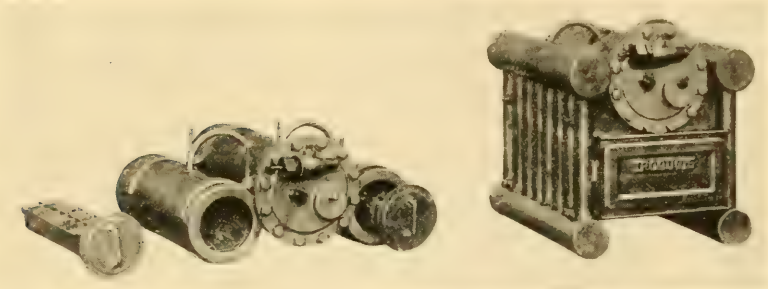


FIG. 97.—IROQUOIS COOLING UNITS. APARTMENT HOUSE UNIT AT LEFT.

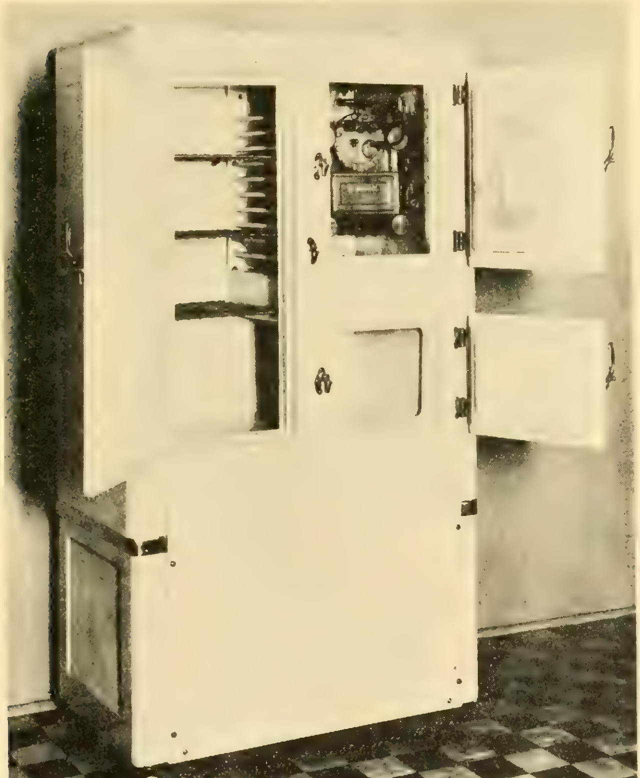


FIG. 98.—IROQUOIS SYPHON ALL-METAL CABINET EQUIPPED WITH COMPLETE SELF-CONTAINED REFRIGERATING UNIT.

fans, one on the motor shaft and the other on the compressor flywheel.

The automatic pressure controlled switch is shown in Fig. 95. This device consists of the powerful snap, switch actuated

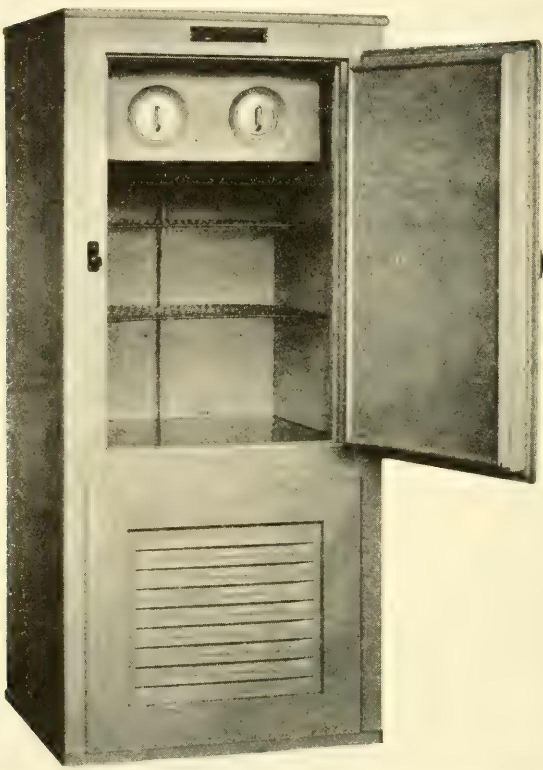


FIG 99.—IROQUOIS ELECTRICAL REFRIGERATOR, APARTMENT HOUSE TYPE.

by a diaphragm subjected to a pre-determined pressure in the cooling unit.

The cooling units, as Fig. 97, are constructed of heavy tinned copper and brass material. A float valve is used to control the flow of liquid refrigerant to the cooling unit.

Figs. 98 and 99 show a typical cabinet equipped with the refrigerating unit forming a complete self-contained model.

Isko—First Model.—The first model Isko machine is described as follows:

The motor operates the compressor and is controlled through the thermostat and the circuit breaker. When the refrigerator gets warm the themostat starts the motor, which runs until a predetermined low temperature is attained and then stops. The thermostat is located in the cooling coil where the greatest variation of temperature is, there being nearly 32° of variation under average conditions. The thermostat alternates on from 2° to 4° of variation.

Isko cools the refrigerator by abstracting the heat through the tinned copper ice-making coils in which liquid sulphur dioxide is being boiled by the heat extracted from the refrigerator.

This sulphur dioxide steam, unlike the steam with which we are most familiar, is cold (14° F.). This is sucked into the compressor at atmospheric pressure and elevated in both temperature and pressure to the corresponding temperature of the room.

In the condenser (which is a coil of pipe surrounding the apparatus as a guard), this warm sulphur dioxide steam loses its heat by radiation to the surrounding atmosphere, causing it to liquefy becase it is under pressure.

The liquid coming out of the bottom of the condenser is fed automatically into the tinned coil inside the refrigerator by means of an expansion valve, which works intermittently to step down these condenser pressures to a pressure above atmospheric pressure.

Moisture abstracted from the refrigerator is deposited on the coil, and freezes because the coil is at 14° F. The machine operates intermittently so that this frost does not accumulate. On the stand-still period the frost will melt and run off through the drain pipe of the refrigerator.

In the ice-making compartment it is possible in warm weather to make 32 cubes of ice in a day of twenty-four hours, automatically. Ice can be made in winter only when the refrigerator is in a well-heated room; otherwise the machine will run too small a percentage of the time.

The complete machine is supplied as a unit ready to run when connected to an electric light socket. The number 1

size will take care of an ordinary refrigerator not to exceed fifty-five square feet of internal exposed area when set over a hole thirteen inches by thirteen inches in the top of the refrigerator. The actual weight of the apparatus is 175 pounds.

Isko—Present Model.—The present model of the Isko ma-

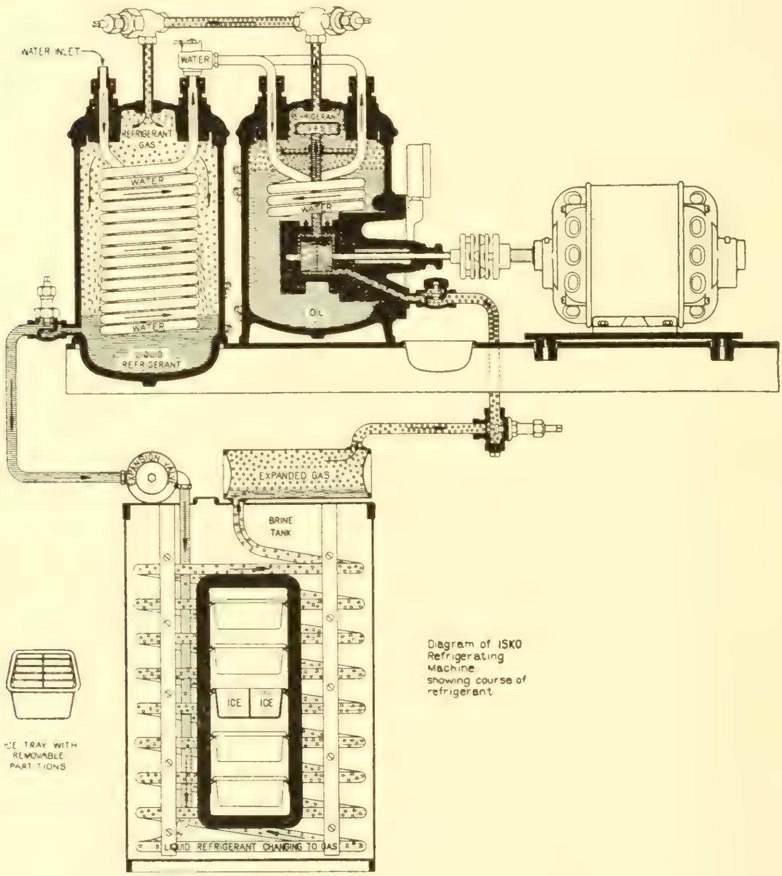


FIG. 100.—ISKO REFRIGERATING MACHINE.

chine is shown in Fig. 100. This machine was formerly manufactured in large quantities by the Isko Company at Chicago.

The compressor was of the herringbone gear type, operating at motor speed submerged in a sealed chamber of oil.

The gears were supplied with a small amount of oil to seal them so that they would compress the sulphur dioxide gas, this being the refrigerant used.

The cylinder and motor were mounted on a single base to be placed on the top of the refrigerator or in the basement, if desired. The motor was directly connected to the gear shaft through a flexible coupling.

Brine tanks were made in various sizes. An expansion valve was used, expanding into a copper tube immersed in the brine.

A small header was used on the suction line between the evaporating coil and the compressor to prevent frosting back to the machine.

The condenser was water-cooled by means of a copper coil inside the condenser cylinder. Part of the cooling water circulated through a coil in the compressor cylinder, in order to cool the oil in which the gears operate.

Full automatic controls were used to maintain a uniform temperature inside the refrigerator.

Kelvinator.—Fig. 101 shows the Model Senior (2 cylinder) refrigerating machine made by the Kelvinator Corporation, Detroit, Michigan. This is a motor-driven refrigerating machine designed for installation with any refrigerator of standard construction of not over 70 cubic feet contents.

The condensing unit consists of the motor, compressor, and condensing coil mounted on a single base and is installed in the basement or other out-of-the-way place.

The compressor is of the reciprocating, single-acting type. Piston valves and discharge valves are of the disc type. The pistons slide in steel sleeves. Instead of a stuffing box a sylphon gas seal of self-aligning, self-lubricating, anti-friction metal is used. It is driven through a combined flywheel and fan by a "V" belt. The motor is of the repulsion induction type, ¼ hp.

The condenser is a continuous coil of ½ inch seamless copper tubing wound spirally and charged with sulphur dioxide. It is air-cooled and therefore is not dependant on any water supply for its proper operation.

Fig. 102 shows the Model Junior (1 cylinder) refrigerating machine. This is similar to the Model Senior except that it is installed with refrigerators of not over 20 cubic feet contents.

The refrigerating element consists of the brine tank, the expansion coils inside the brine tank, the expansion valve, the thermo-coil and the thermostat. Eighteen standard sizes of brine tanks are made, one of which is shown in Fig. 103 and fit practically all ice chambers.

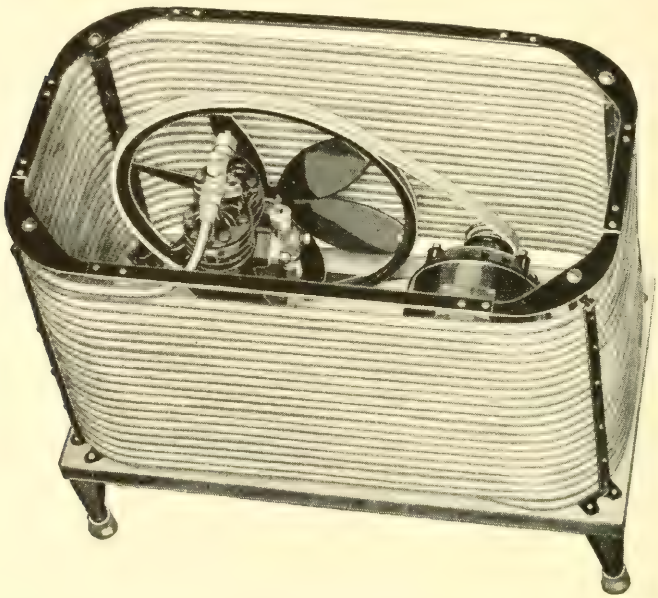


FIG. 101.—KELVINATOR TWO-CYLINDER REFRIGERATING MACHINE.

The brine tank is of sheet copper tinned on the outside. It has two to four freezing compartments, according to the tank size. Each 21-cube tray will freeze two and one-half pounds of ice, while the large tray will freeze an eight and one-half pound cake of ice. The tank is filled with a solution of calcium chloride. Expansion coils are placed in the tank in such a way as to surround each freezing compartment.

The liquid refrigerant is admitted to the expansion coils through an automatic expansion valve which lowers its pres-

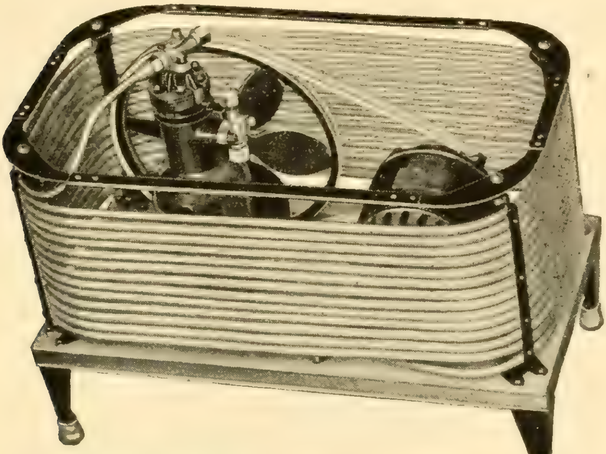


FIG. 102.—KELVINATOR SINGLE-CYLINDER MACHINE.

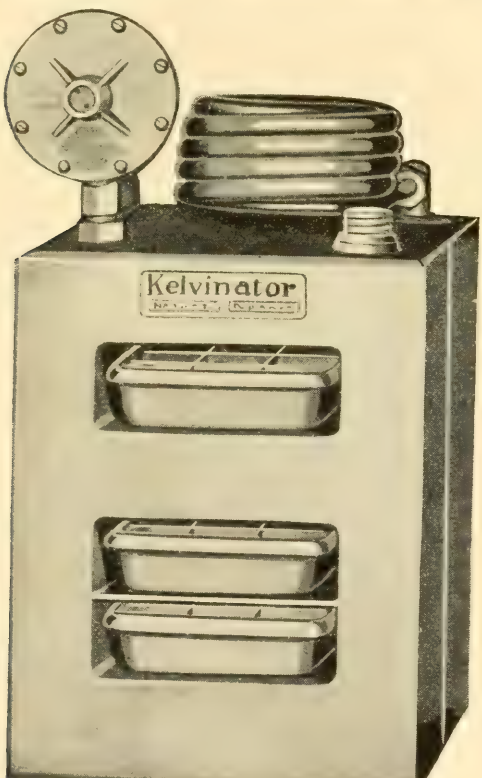


FIG. 103. KELVINATOR COOLING UNIT.

sure from two inches of vacuum to three pounds per square inch, depending on the size of brine tank and number of feet of tubing in the expansion coil. The valve is of the balanced pressure type. Increasing pressure on the low side caused by the boiling refrigerant, acts against the pressure on the liquid side and automatically shuts off the supply of liquid when sufficient has been admitted. The valve automatically opens when the suction of the compressor sufficiently reduces the pressure on the low side.

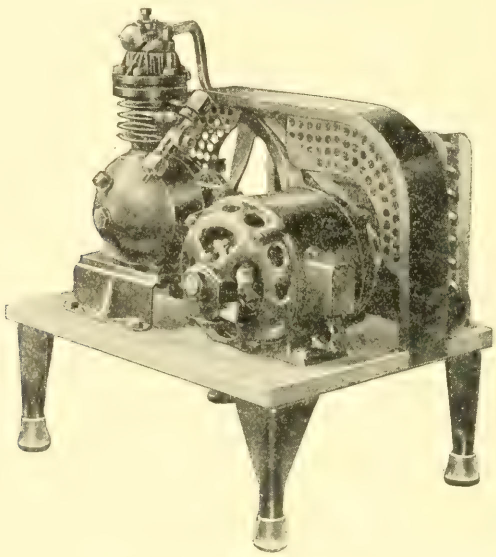


FIG. 104. KELVINATOR CONDENSING UNIT.

The system is automatically controlled by the thermostat placed within the thermo-coil on top of the brine tank. The thermostat opens and closes the motor circuit as the temperature within the refrigerator falls and rises. It is of the sylphon type, a corrugated metal bellows filled with sulphur dioxide, which by the contraction and expansion caused by changing temperatures operates the quick make and break switch.

The actual running time of Kelvinator will vary, of course, with the room temperature, the quality and degree of refrigerator insulation, the size of refrigerator, etc. Under ordinary conditions, however, the machine will run 6 or 7 hours a day.

The box temperatures will be at least 10° colder than ice would keep the same box. The reason for this is that the surface of the brine tank is kept constantly at 20° to 22° while the surface of a cake of ice is 32° F.

Fig. 104 shows the condensing unit Model 12800. This unit includes a 1/6 hp. motor driving a reciprocating type,

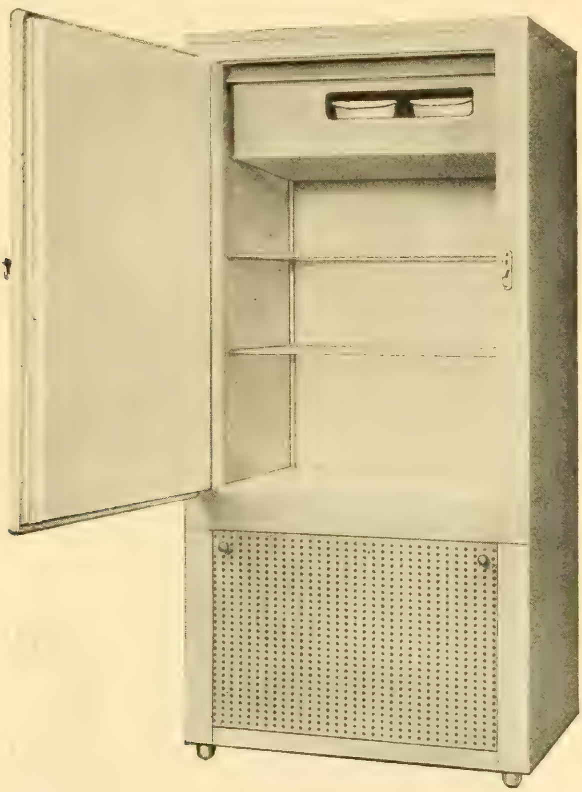


FIG. 105.—SPECIAL STEEL CABINET EQUIPPED WITH CONDENSING UNIT SHOWN IN FIG. 104.

single-cylinder compressor by means of a "V" type belt. The condenser is made of finned tubing. It is cooled with forced air circulation. A small receiver is used. The weight of this unit is 80 pounds.

This unit is supplied with a special steel cabinet, Fig. 105. The food storage space is 4.7 cubic feet and 7 square feet shelf area. The exterior is gray lacquer on steel. The lining

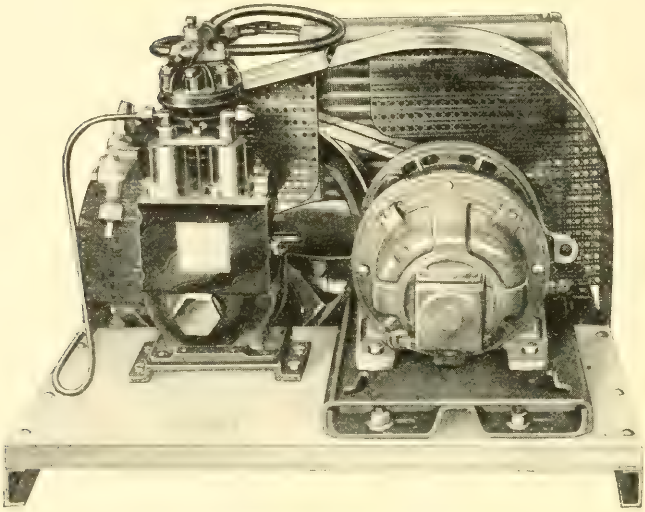


FIG. 106.—KELVINATOR TYPE "LB" LARGE CAPACITY AIR-COOLED CONDENSING UNIT.

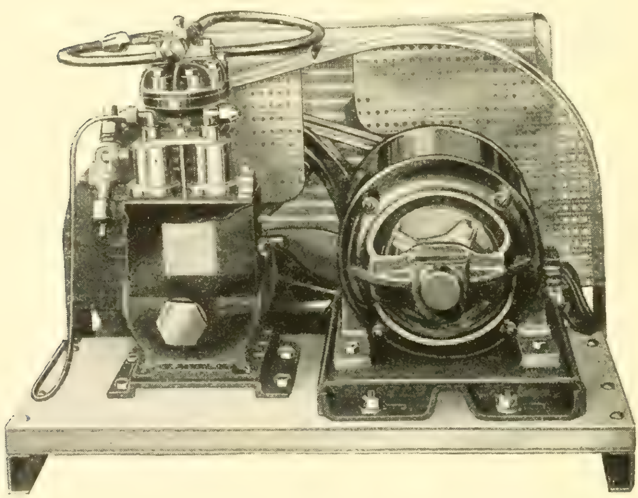


FIG. 107.—KELVINATOR, TYPE "BB".—COMPRESSOR HAS TWO CYLINDERS.

is white enamel on galvanized iron. The hardware is nickel-plated brass. The insulation is corkboard. The dimensions of the cabinet are:

	Width	Depth	Height
Overall	26½ in.	22½ in.	56⅛ in.
Food Compartment	22 in.	15 11/32 in.	24⅛ in.
Condensing Unit Compartment	26¼ in.	19 1/32 in.	16 5/32 in.

The cooling unit has two 15-cube ice trays. The shipping weight of this unit is 300 pounds.

Fig. 106 shows the type LB large capacity air-cooled condensing unit.

The compressor has one cylinder and is of the vertical, reciprocating, single-acting type. A ¾ hp. motor drives the compressor by means of a "V" type belt. The condenser is of the radiator type. It is cooled by forced air circulation, from the fanned motor pulley. The wattage is approximately 800 at rated capacity.

A similar larger type BB, Fig. 107, is manufactured. The compressor has two cylinders. A 1½ hp. motor is used. The wattage of this model is approximately 1200 at rated capacity. Both of these units have extensive use for apartment house installations.

Kold King.—Fig. 108 shows the household refrigerating machine manufactured by the Kold King Korporation at Detroit, Mich. It is reported this company is out of business.

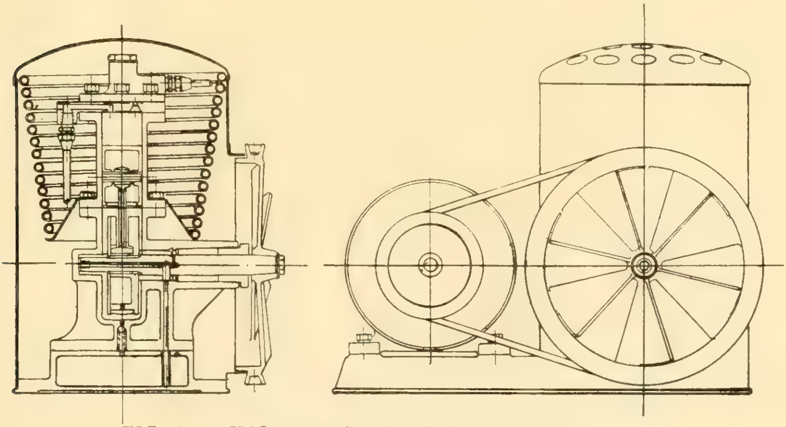


FIG. 108.—KOLD KING REFRIGERATING MACHINE.

A single-cylinder, sulphur dioxide compressor is used. The condenser is air-cooled and consists of sixty feet of copper tubing, forming a spiral coil around the compressor. A fan in the compressor fly wheel forces air over the condenser coil. The suction and discharge valves are of the flat steel flapper type. They are both located in the cylinder head plate. The compressor is driven by a 1/6 hp. phase, repulsion-induction motor. A "V" type belt is used for the means of driving.

A float valve system of expansion has been developed for regulating the cooling compartment. The thermostat is attached to the crank case and is controlled by pressure. A brine tank is used which is placed in the ice compartment of the refrigerator.

The mechanical unit is supplied to refrigerate any standard cabinet.

Lipman Refrigerating Machine.—Fig. 109 shows the household size refrigerating machine, which is made by the Lipman Refrigerator Car & Mfg. Company, Beloit, Wis.

This company has specialized for years in producing refrigerating machines using ammonia as a refrigerant and operating with full automatic controls.

The motor, compressor, condenser, water valve, and high pressure cut-out, are mounted on a simple base to form a compact unit. A "V" belt drive is used, thus eliminating the need of an idler pulley.

The condenser is water-cooled. The water valve is automatically opened when the machine is operating, by an attachment on the outer end of the compressor shaft. A safety feature is included so that the machine will not operate should the supply of cooling water fail.

The operation of the machine is controlled by a thermostat placed in the food compartment. The motor starts or stops automatically when the temperature in this compartment varies only a few degrees.

An expansion valve is used to control the supply of refrigerant to the cooling coil. The household model uses only a few ounces of liquid ammonia in the entire system.

This machine is supplied with a cooling element to be placed in the ice compartment of the customer's refrigerator. This cooling element consists of a direct-expansion coil and a sharp freezer of steel pipe in which ice cubes or frozen desserts may be made. A cast iron sleeve is inserted in the horizontal part of this direct-expansion coil to form the sharp freezer.

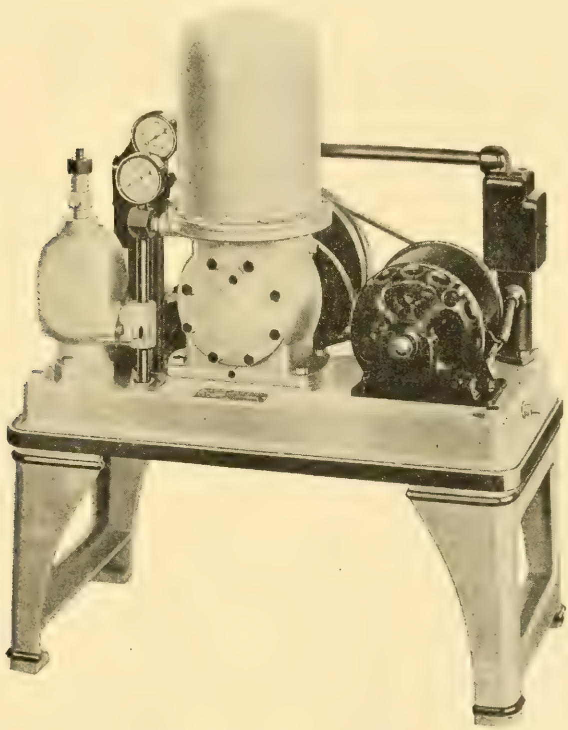


FIG. 109.—LIPMAN REFRIGERATING MACHINE.

Larger automatic machines are built for installations requiring a larger capacity machine.

Merchant and Evans.—Fig. 110 shows the electrical refrigerating system manufactured by Merchant and Evans Company of Philadelphia, Pa.

A low temperature liquefying gas is compressed (G), into coils (C), which are cooled by a fan on the pulley and thus

becomes a liquid which flows into the freezing chamber (F) through the Control Valve (V).

Here the liquid boils by absorbing heat from the interior of the box, cooling it to a temperature of 45° F. The thermostat

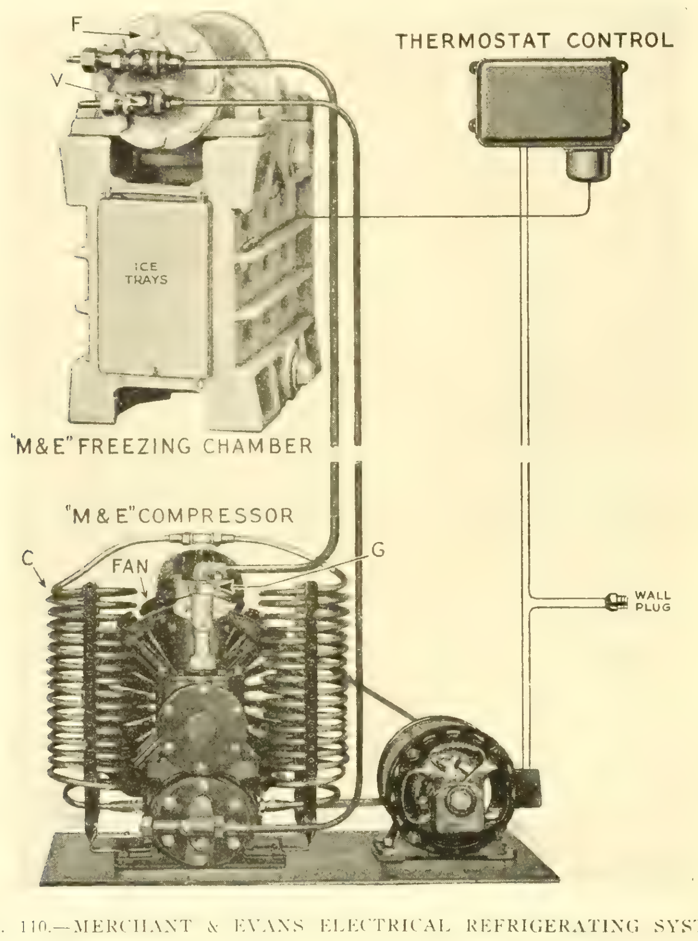


FIG. 110.—MERCHANT & EVANS ELECTRICAL REFRIGERATING SYSTEM.

then turns off the current automatically until the box temperature rises to 50° F. The thermostat then again starts the motor and the whole process is repeated until the box temperature again drops to 45° F.

The compressor is a single cylinder of the single-acting vertical reciprocating type, with long stroke.

The condenser consists of two coils of copper tubing placed on opposite sides of the compressor. Fan blades in the compressor flywheel are used to force air over the two condenser coils.

FIG. 111.—MERCHANT & EVANS REFRIGERATING SYSTEM INSTALLED.

The freezing chamber is made of galvanized cast iron and tested to 350 pounds pressure per square inch.

Fig. 111 shows a typical installation in a cabinet. Steel cabinets are supplied in sizes from 7 to 20 cubic feet inside capacity.

Norge.—The Detroit Gear & Machine Company manufacture an electric refrigerating machine for the Norge Corporation, Detroit, Michigan. This machine has been adopted for domestic use by McCray Refrigerator Company of Kendalville, Ind. The refrigerant used is sulphur dioxide.

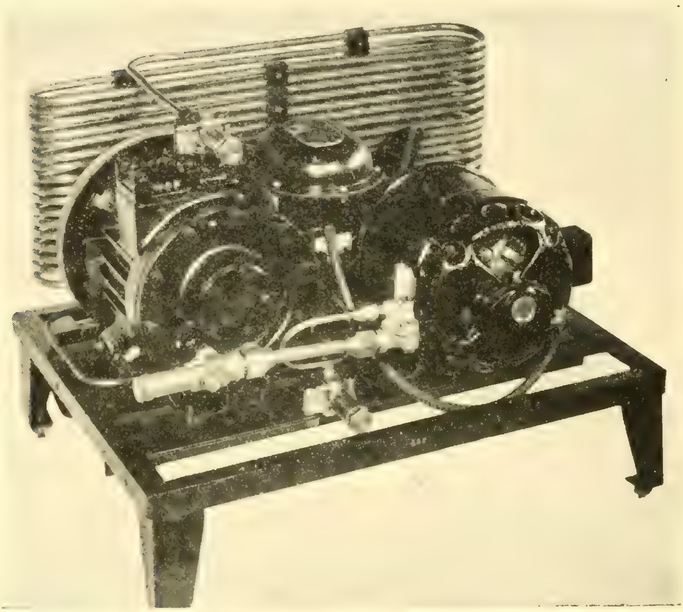


FIG. 112.—NORGE UNIT MOUNTED ON STEEL BASE.

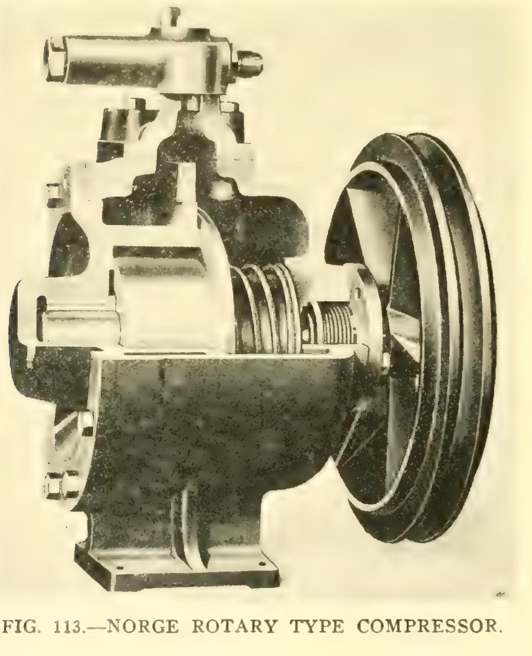


FIG. 113.—NORGE ROTARY TYPE COMPRESSOR.

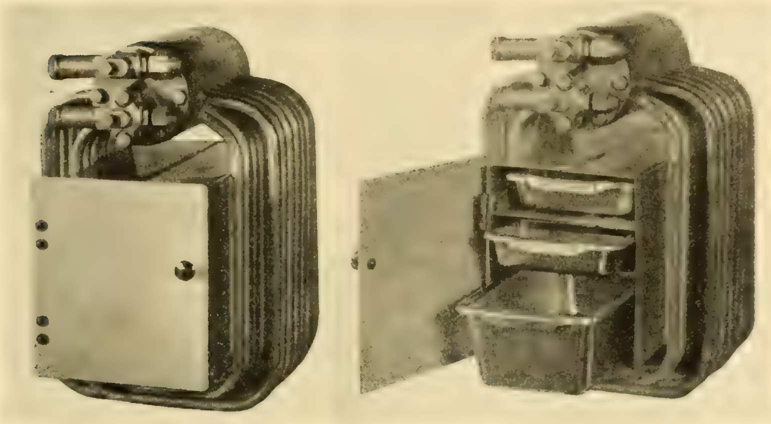


FIG. 114.—NORGE FREEZER COILS.

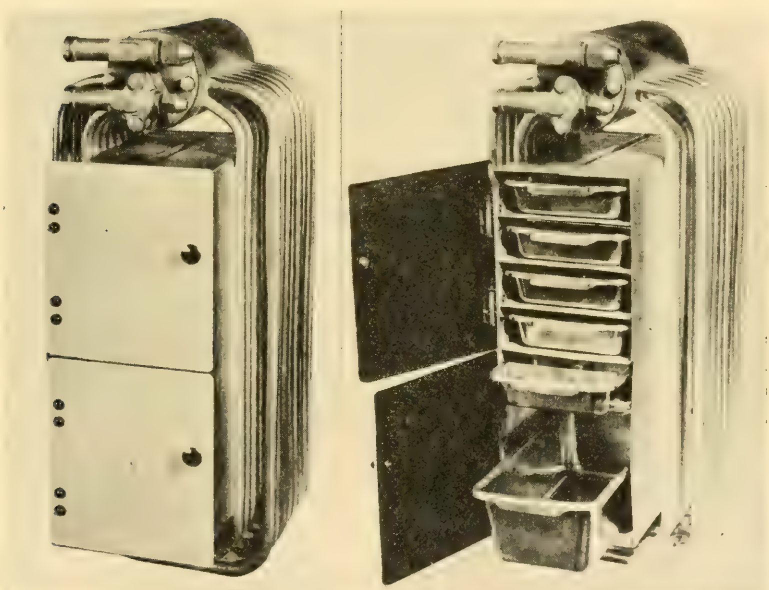


FIG. 115.—NORGE FREEZER COILS.

Fig. 112 shows the condensing unit consisting of the compressor, motor, condenser and automatic control mounted on a steel base.

The compressor, Fig. 113, is of the rotary type. The rotor is driven by an eccentric on the crank-shaft. It moves with a gyratory motion, opening the intake and permitting entrance

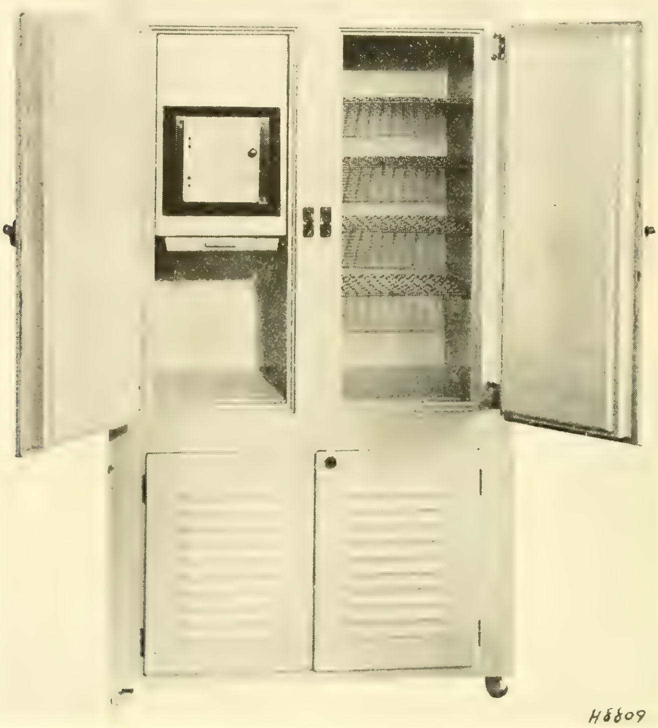


FIG. 116.—NORGE ELECTRICAL UNIT IN McCRAY REFRIGERATOR.

of the Sulphur Dioxide gas into the compression space. The gas escapes through the discharge valve. An oscillating blade always maintains contact with the rotor, and separates the suction chamber from the discharge chamber. This blade, as well as all other moving parts, is submerged in oil under pressure. The rotor fits into the cylinder in such a way that it automatically adjusts and takes up whatever wear may occur.

Figs. 114 and 115 show freezer coils of various sizes. These are equipped with white enameled swing doors which cover the ice tray openings. This prevents frost forming in the trays and eliminates food odors from the freezing pans.

Fig. 116 shows an electrical unit installed in a McCray refrigerator.

Odin.—The Odin refrigerating machine is made by the Automatic Refrigerating Company of Hartford, Conn.

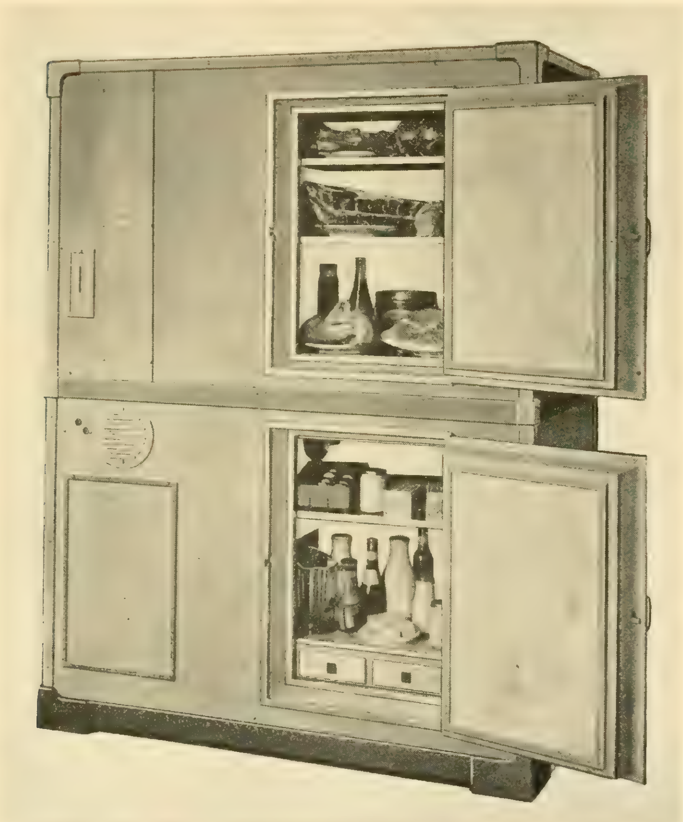


FIG. 117.—ODIN REFRIGERATING UNIT.

This machine uses air under very low pressure for a refrigerating medium. The machine is entirely automatic. A thermostat in the food compartment automatically starts and

stops the refrigerating machine. This system is air-cooled, thus eliminating cooling water connections.

The cabinet, Fig. 117, has fifteen cubic feet of food compartment space. An ice making compartment is included. This box has a gray enamel finish on the outside and porcelain fused on a metal lining.

Rice.—A complete line of fourteen distinct models of refrigerating units for domestic use are manufactured by Rice Products, Inc., of New York City.

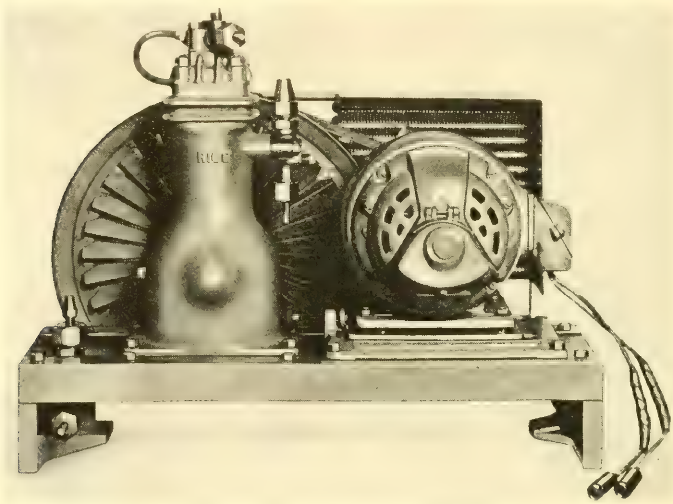


FIG. 118. RICE COMPRESSOR UNIT.

Nine of these are designed for installation in conjunction with refrigerators ranging from five to sixty cubic feet in size, and consist of a compressor unit and a cooling unit. The latter is placed in the ice compartment of the refrigerator to be cooled and the compressor unit can be placed in the basement immediately beneath the refrigerator or other convenient location. The compressor and cooling units are connected by two small copper tubes. Five models known as D-5, D-7, D-9, D-12, and D-15 are complete self-contained electrical refrigerators ready for electrical connection to the lighting mains.

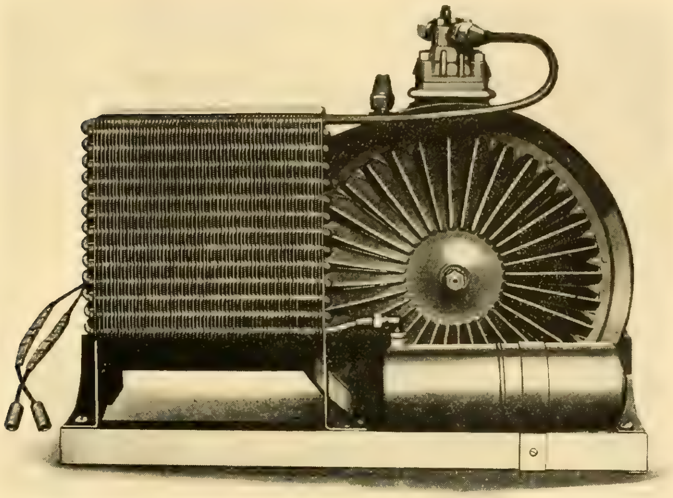


FIG. 119.—ANOTHER VIEW OF THE RICE COMPRESSOR UNIT.

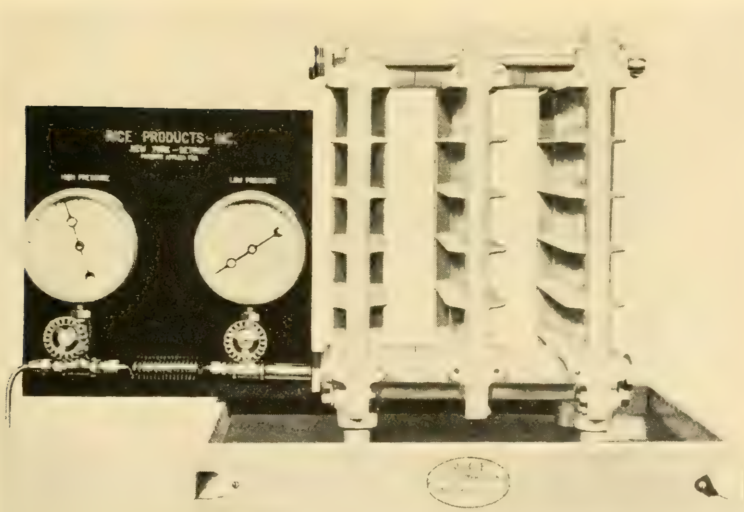


FIG. 120.—RICE GRID SECTIONS, MADE OF SEMI-STEEL CASTINGS, TONGUE AND GROOVE CONNECTED.

Fig. 118 and 119 show two views of the compressor unit. This consists of a compressor, motor, fly-wheel, fan pulley, belt, condenser, receiver with the necessary shut-off valves

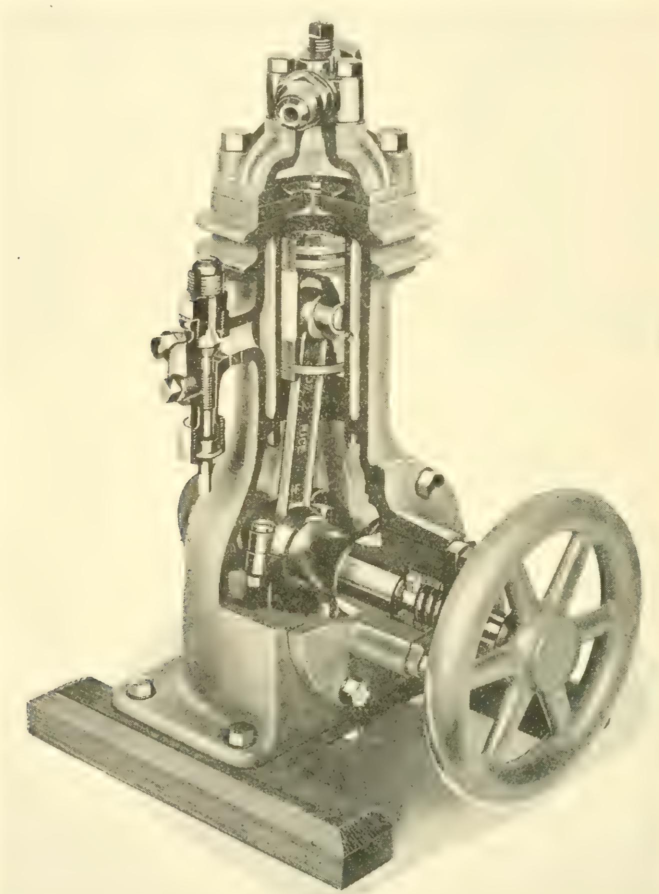


FIG. 121. SECTIONAL VIEW OF RICE COMPRESSOR.

and strainer, all mounted on a substantial iron base. Both single and double cylinder compressors are furnished. The former is driven by ¼ hp. motor at 360 r.p.m. and the latter by a ½ hp. motor at the same speed.

Fig. 121 is a sectional view of the compressor. Compressors are of the single-acting, vertical reciprocating type, air-cooled and lubricated by splash from the crankcase. They are belt driven by means of a moulded rubber and canvas "V" belt passing over the compressor fly-wheel which is 14¾ inches in diameter. Crank shafts are of forged steel, heat treated and ground and are 1¼ inches in diameter on both types. Main bearings are of cast iron 1⅜ inches x 1¼ inches. An approved ball thrust bearing, to take the thrust of the seal spring is provided. Connecting rod bearings are babbitt broached to size and measure $1\frac{3}{16}$ inches x 1¼ inches. Bunting (bronze) bushings are used in the wristpin bearings.

Pistons are of cast iron with suction valve mounted flush with the head. They are fitted with six piston rings; two in each of the three ring slots. Both suction and discharge valves are of the feather type, of new and improved design. Valves are individually lapped to their seats and are noiseless in operation. The discharge valve plate is a die casting.

A metallic stuffing box of special design has been provided. The seal ring is lapped to a seat formed by a shoulder on the crankshaft and is kept in contact by means of a sixty-pound spring. The bar and stroke on both compressors is $1\frac{13}{16}$ inches x $1\frac{13}{16}$ inches.

Motors are regularly supplied for either 110 or 220 volt, 60 cycle, single phase alternating or 110 or 220 volt direct current. Motors wound for other voltages, frequencies or phases can be furnished to order at additional cost. Motors, as regularly supplied, are furnished with sliding bases to facilitate belt adjustment and dispense with idlers.

Condensers are of the Flint-lock type and are mounted at the back of the compressor unit. They are cooled by a fan mounted directly on the motor-shaft. The condenser assembly is self-supporting and mounted on the base. Condensers furnished with the Type "A" Compressor Unit measure 9 inches x 9 inches. Those furnished with the Type "B" measure 12 inches x 12 inches.

Compressor Units are finished in dark blue Duco. Dimensions are as follows, overall:

Type "A"
25 in. long
17½ in. deep
19¼ in. high

Type "B"
29 in. long
18¾ in. deep
19¼ in. high

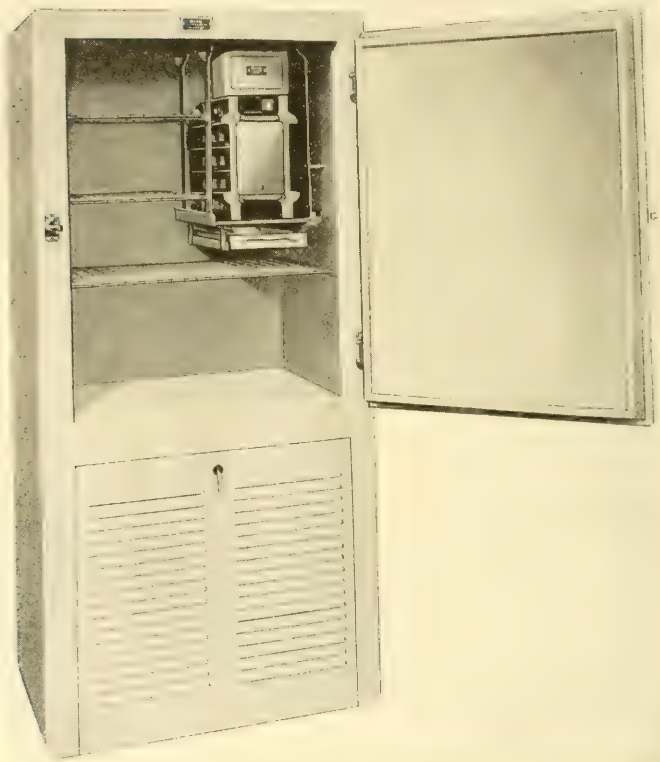


FIG.—122.—RICE METAL CABINET.

Net Weights: Type "A" 140 lbs. Type "B" 185 lbs.

The cooling unit, Fig. 121 consists of a series of grid sections made of semi-steel castings, tongue and groove con-

nected. These various sections can be assembled in grids to meet any domestic requirement.

Grids are galvanized both inside and out and are tested to 300 pounds air pressure under water and 350 pounds hydro-

FIG. 123.—RICE METAL CABINET.

static pressure. Grids are dehydrated under a vacuum at the factory and sealed prior to shipment.

Ice trays are of tinned copper and measure 10⅝ x 3⅝ x $1\frac{9}{16}$ inches deep and hold approximately one pound of water. Each tray is provided with a removable grid for forming cubes.

There are twelve 1½ x 1½ x 1⅜ inch cubes per tray. This is the standard ice tray furnished with all cooling units

A particularly interesting feature consists in the elimination of the float or expansion valve, and the substitution therefor of a capillary tube, having no moving parts and no adjustment.

The thermostat is a Mercoid Control manufactured by the American Radiator Company. It is temperature controlled and is provided with both temperature and differential range adjustments. The circuit is controlled direct to the motor and accordingly no relays, transformers or other intermediate controls are required. Contacts are sealed within a glass tube containing an inert gas which prevents oxidation or corrosion, a common fault with most thermostatic controls.

Figs. 122 and 123 show typical metal cabinets. The standard construction is an exterior of steel finished in white Duco and an interior of porcelain on steel. Doors are provided with double gaskets. The insulation is of corkboard two inches thick sealed between interior and exterior metal with hydrolene cement. The cabinet specifications of the five self-contained models are as follows:

CABINET SPECIFICATIONS

Model	D-5	D-7	D-9	D-12	D-15
Width	27¾ in.	34½ in.	34½ in.	45 in.	54½ in.
Depth	24¾ in.	28½ in.	28½ in.	28½ in.	28½ in.
Height	60 in.	63 in.	69 in.	69 in.	69 in.
Weight	460 lbs.	530 lbs.	612 lbs	665 lbs.	781 lbs.
Gr. Capacity	6.5	10.3	12	16	19.3
Food Storage	5	7	9	12	15
Shelf Space	8.3	9.2	12.2	17	23.2
No. Cubes	36	48	60	72	120
Compr. Unit	Type "A"	Type "A"	Type "A"	Type "A"	Type "A"
Cool. Unit	No. 6	No. 10	No. 15	No. 25	No. 30

Sanat.—The Sanat machine, Fig. 124, is made by Sanat Refrigerating Co., Inc., 331 Madison Avenue, New York City.

The machine consists of a motor, a worm and worm gear drive, a compressor, a condenser, an expansion valve, a cooling tank, a temperature control, and the necessary piping and wiring to connect the units. The other elements are the refrigerant and the brine.

The refrigerant is chloric ether, a solution of ethyl chloride and alcohol. The pressure of condensation is relatively low, 16 to 20 pounds gauge.

A ¼ hp. motor is used to drive the compressor by means of a worm and worm gear drive. Radial and thrust ball bearings are used for mounting the worm, and friction is thereby greatly reduced.

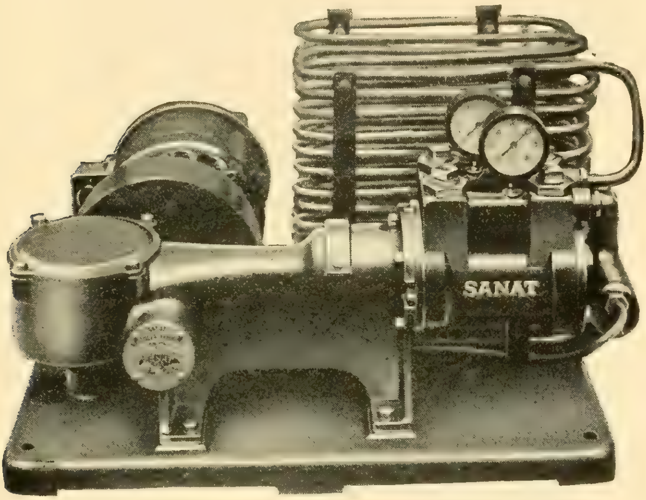


FIG. 124.—SANAT REFRIGERATING UNIT.

The compressor is a single cylinder, double acting, slow speed machine operating at forty strokes per minute, or eighty compressions. Poppet valves are used throughout—bakelite operating on brass seats, eliminating metal to metal contact with its attendant sticking. The bearings on the crank shaft and connecting rod are of hardened steel and amply large. The stuffing box is of the double gland stype. The compressor is lubricated automatically by the mineral oil which is formed when the refrigerant is expanded into the brine.

The condenser is air cooled and consists of a hundred feet of ⅜-inch copper tubing. No forced draught is required over these coils to condense the refrigerant, therefore, the need for a fan is eliminated.

The expansion valve is a simple device which runs into the brine within a few inches of the bottom of the tank. This valve releases the chloric ether into the brine from the high to low pressures. The expansion member of this mechanism is a sylphon bellows, which expands or contracts through very narrow limits, thus eliminating or keeping adjustments to a minimum.

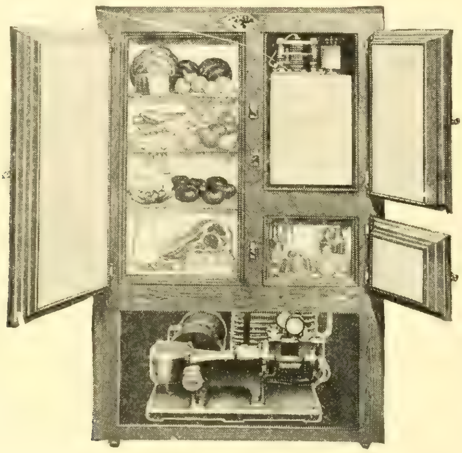


FIG. 125. COMPLETE SANAT UNIT INCLUDING CABINET.

The cooling tank, made of ⅛-inch steel, occupies the space in the ice compartment of the refrigerator and contains the solution of calcium chloride brine and alcohol. The refrigerant is expanded directly into the brine causing an agitation which produces an even temperature throughout the brine and results in a constant crisp dry-cold in the refrigerator. A marked advantage of this system lies in the fact that the agitation resulting from the direct expansion of the refrigerant into the brine produces an emulsion, which is equivalent to a medium grade mineral lubricating oil. This lubricant is formed in small but sufficient quantities and is drawn back into the compressor and automatically solves the lubricating problem.

The temperature control operates on a ten volt circuit; a relay mounted in a convenient location being used to reduce the voltage from the usual home pressures. This arrangement

requires the minimum of attention. The thermostat is governed by the temperature of the brine and can be set to operate accurately between small variations of temperature.

Fig. 125 shows a complete unit including the cabinet. Fig. 126 shows the cabinet with vegetable storage space at bottom as arranged when the machine is located in the basement.

FIG. 126. SANAT METAL CABINET WITH VEGETABLE STORAGE.

Savage.—Fig. 127 shows the mercury refrigerating machine made by the Savage Arms Corporation, Utica, New York, suitable for ice cream cabinet and household fields.

Fig. 128 shows the machine with the condenser removed. This machine operates on a new system of mercury compression.

The screw pump, invented by Archimedes about 250 B. C.,

using mercury as the compressing fluid, is the basis of the design. Following are the most important advantages:

There are no internal moving parts. There is no lubricant within the refrigerating cycle.

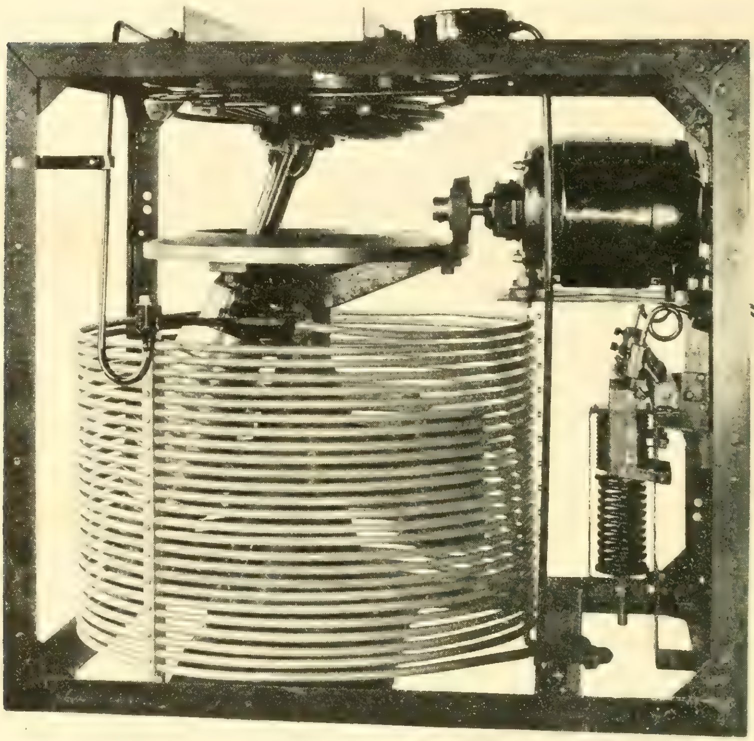


FIG. 127.—SAVAGE MERCURY REFRIGERATING MACHINE.

The drive is external to the refrigeration cycle, requiring no stuffing box or gland joint. The system is sealed by welding, and is leak proof.

The machine is exceptionally quiet in operation, due to purely rotary motion at relatively low speeds.

Mercury compression, because of its inherent freedom from power losses, makes possible an exceedingly low power consumption per unit of refrigeration.

Excessive pressures cannot be generated, since the critical point of the mercury compressor is reached only a few pounds above the working pressure of the machine. It then blows back, short circuiting itself.

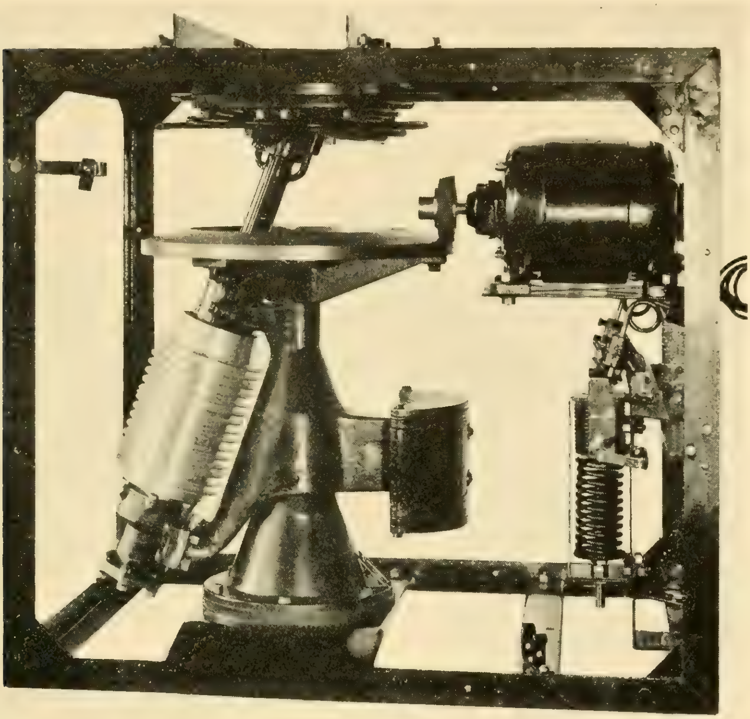


FIG. 128.—SAVAGE MERCURY REFRIGERATING MACHINE WITH CONDENSER REMOVED.

A force feed oiling system provides adequate lubrication to the four external bearings with oil storage capacity sufficient for many years of operation.

An automatic temperature speed control gives the machine added refrigerating capacity as the room temperature rises. The machine automatically operates at the most efficient speed for all room temperatures, an exclusive feature.

Service may be performed upon any mechanical or electrical part of the machine without disconnecting or disturbing the refrigeration system, and without losing any refrigerant.

It is obvious that there can be no piston leakage, since each mercury piston seals itself in the helical passageway. Neither can there be any clearance or re-expansion loss, since each gas volume is pushed completely through from the low to the high pressure chamber. There is no internal wear.

Fig. 129 is a typical cabinet for preserving ice cream. This cabinet is of angle iron frame construction with tongue and groove spruce flooring.

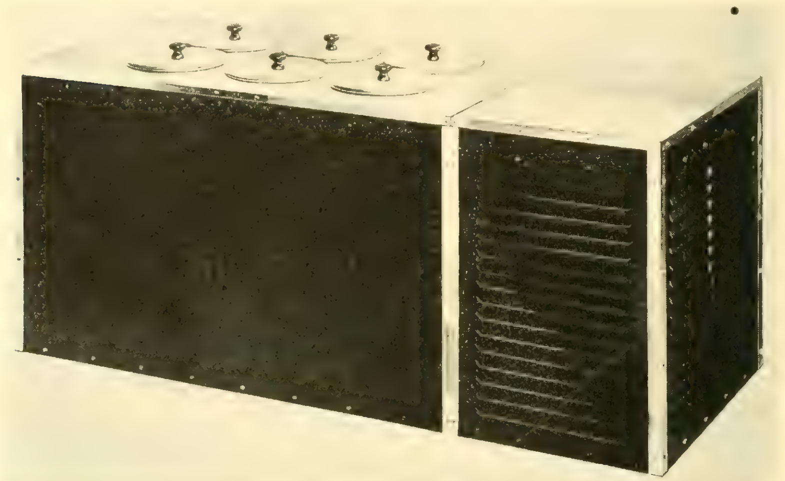


FIG. 129. SAVAGE ICE CREAM CABINET.

Cork insulation is used and all joints flooded with sealing compound. Two thicknesses of waterproof paper are used as an additional protection against air leakage. The lining is of heavy galvanized sheet steel. The top is of laminated wood, covered with non-corrosive metal. The sides are of black-enameled sheet steel, bound in by metal corner angles.

The cabinets may be installed either as a unit with the compressor or as a remote system. In the latter case the compressor unit is generally installed in the basement or in some other convenient place separate from the cabinet.

Servel.—Figs. 130 and 131 shows the Model 21-A refrigerating machine manufactured by the Servel Corporation

whose main offices are at 51 East 42nd Street, New York City.

Methyl Chloride is the refrigerant used in this system.

The compressor, condenser, pressure control and ¼ hp. motor are mounted on a pressed steel base. The 21-A is used in all complete Servel refrigerators, as well as all remote

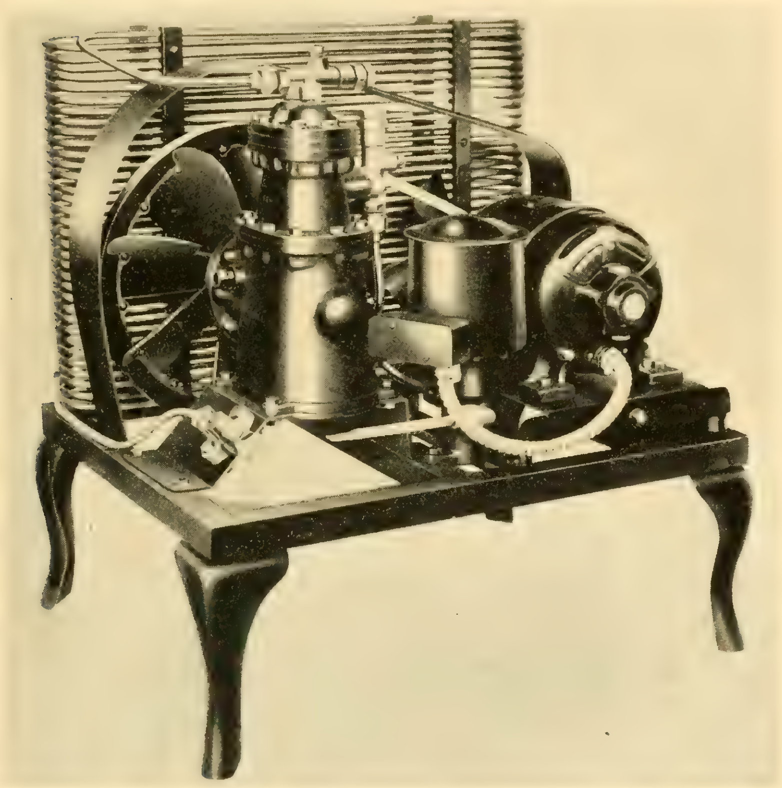


FIG. 130. SERVEL MODEL 21-A REFRIGERATING UNIT.

household installations. The compressor is of the vertical, twin cylinder, single acting, reciprocating type. It is free from vibration and practically noiseless. The bore is 1½ inch and the stroke 1¼ inch. The compressor runs at a comparatively low speed—375 r.p.m. The drive is accomplished through a "V" belt. Both the inlet and outlet valves are flapper valves.

Leakage around the compressor shaft is prevented by use of a special sylphon seal of the rotating type.

The temperature control, Fig. 132, is accomplished by means of the action of the copper bellows connected to the low

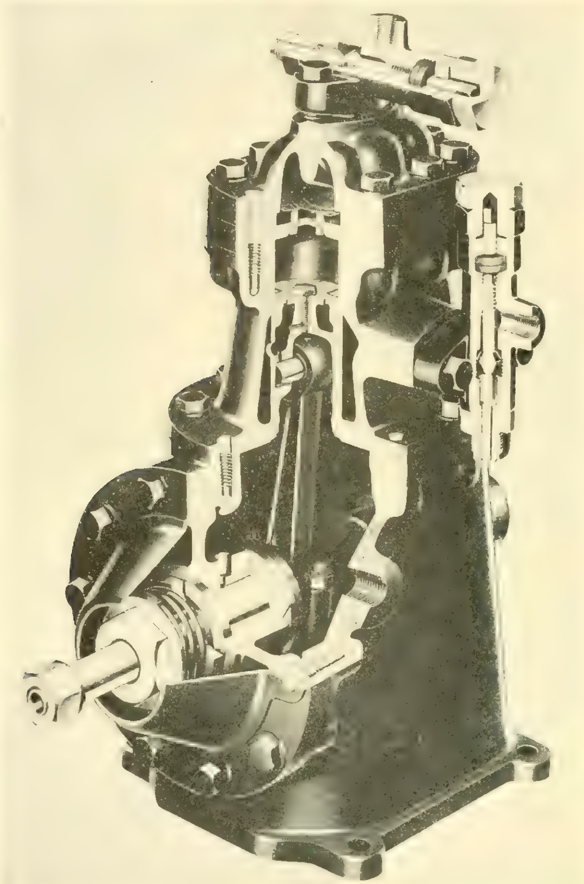


FIG. 131.—CUTAWAY VIEW OF SERVEL COMPRESSOR SHOWING MOVING PARTS AND SYLPHON PACKING.

pressure side of the system. The inflation and deflation of the bellows operates a quick make and break switch, opening and closing the motor circuit, and is adjustable for different pres-

sure to give any desired temperature. A special feature of the control device is that it limits the pressure of the suction gas to the compressor at the time of start so that no overload is placed on the motor.

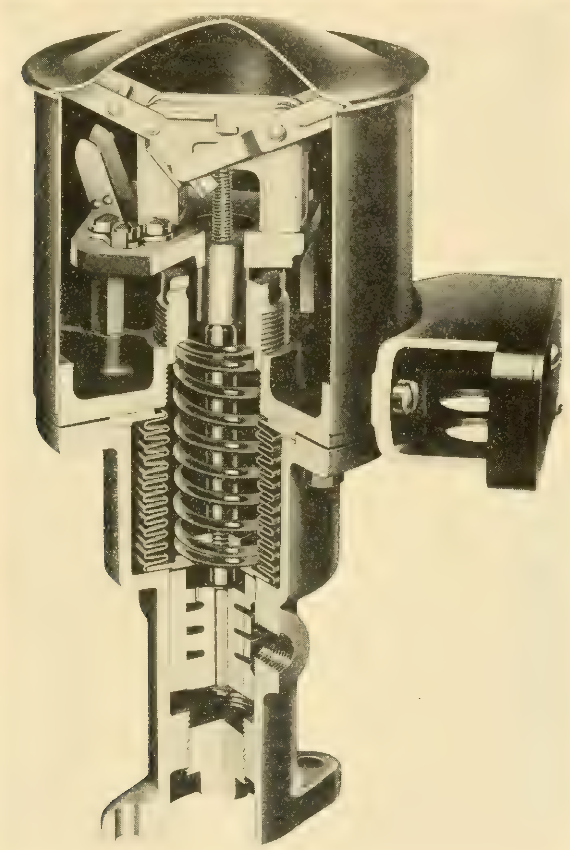


FIG. 132.—SERVEL PRESSURE CONTROL CUT OPEN TO SHOW OPERATION OF PISTON.

The condenser is trombone shaped, cooled by two fans running in opposite directions. The four bladed fan on the motor pulley blows directly into and across the condenser. The large fan on the compressor flywheel draws the air out of the condenser. Exhaustive tests show conclusively that

this arrangement is superior to two fans operating in the same direction and materially reduces the head pressure where boxes are so located as to make air circulation difficult. The motor mounting plate is of pressed steel and adapted to Gen-

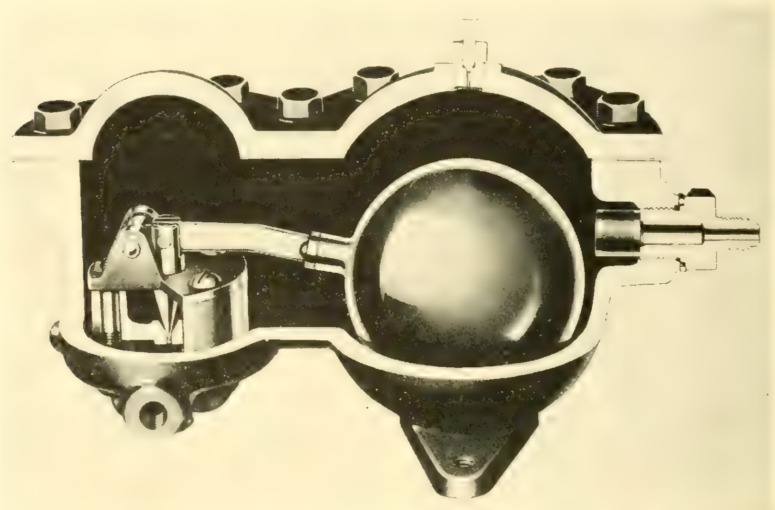


FIG. 133.—FLOAT VALVE, SERVEL REFRIGERATING UNIT.

eral Electric, Century, Emerson and Westinghouse motors. The adjusting of the motor for belt tension is controlled by one nut, making this a very simple operation.

In the complete refrigerator the float valve is placed in the machine compartment. The sturdy construction of this float is clearly shown in Fig. 133. When sufficient liquid methyl chloride has accumulated in the float it raises the ball, opens the needle valve and enters the expansion coils. A cylindrical screen is used as a strainer both on the inlet to the float and as a cage surrounding the needle valve. This prevents any foreign matter clogging the needle valve.

All shutoff valves are made from bronze forgings and are provided with caps which completely inclose the valve stem, thus eliminating leaks through the valve packing.

Fig. 134 shows the Model S-7, suitable for the family of medium size, one of the three all steel models now being man-

ufactured by Servel. The other two models are the S-5, for the small family, and the S-10, suitable for the more pretentious household. (Fig. 135 and 136.)

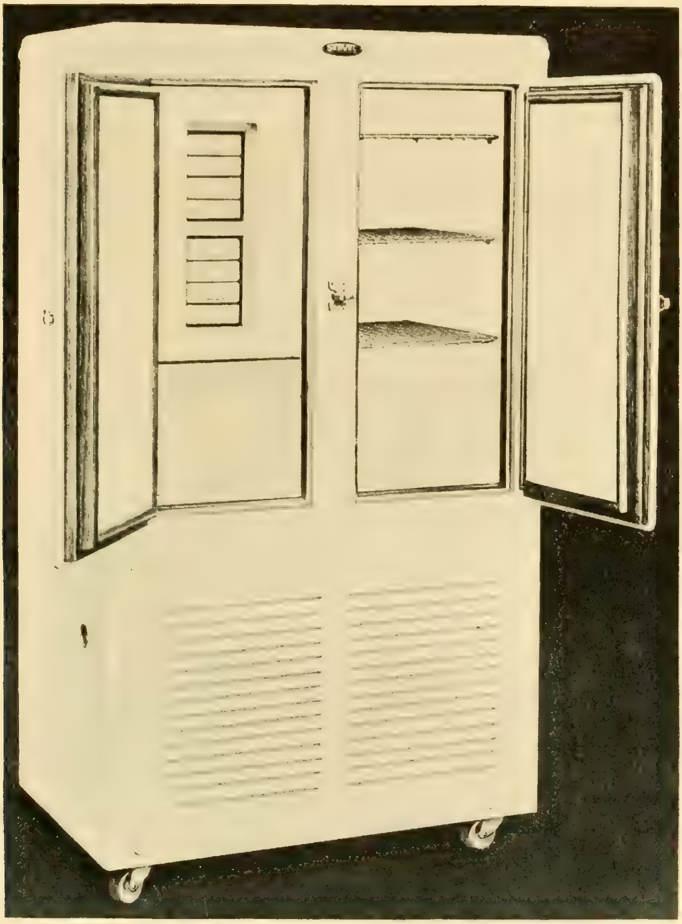


FIG. 134.—SERVEL ALL-STEEL REFRIGERATOR FOR MEDIUM SIZED FAMILY.

The cabinets are constructed of especially selected "Armco" Ingot Iron carefully lead-coated as a positive protection against rust. The metal shell is given an application of oil base primer coat, after which this coat is slowly and carefully baked on under a low temperature, producing a

finish which will neither peel nor scale. Next, several coats of surfacer and two coats of genuine Du Pont White Duco Lacquer are applied and allowed to air dry. The slow process of air drying, while it creates an additional factory cost, pro-

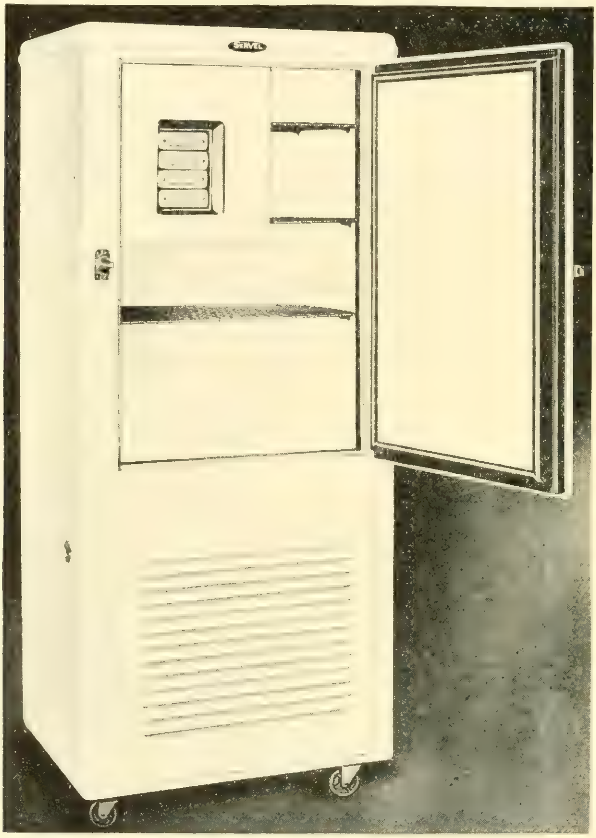


FIG. 135.—SERVEL ALL-STEEL REFRIGERATOR FOR SMALL FAMILY USE.

duces a much better appearing and more lasting finish than can ever be expected under artificial or forced drying.

The porcelian liners are of the box type, and are so constructed, with double lock flanges, that bolt holes or screw holes are entirely eliminated except those required for tank and shelf supports. This produces an absolutely sanitary liner and eliminates all chance of flaking of the porcelain finish, due

to uneven strain such as results from the use of screws or bolts.

The chilling units are of tinned copper and have front

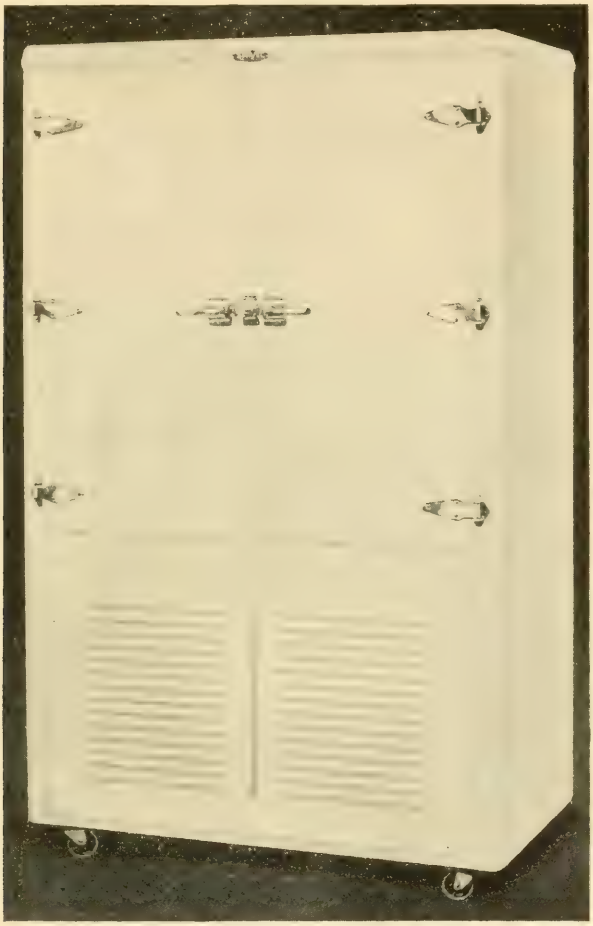


FIG. 136.—SERVEL ALL-STEEL REFRIGERATOR FOR LARGE SIZED FAMILY.

panels and ice-cube-tray fronts of genuine porcelain. Each ice-cube-tray holds 12 cubes.

The insulation is pure compressed corkboard thoroughly impregnated with hydrolene, 1½-inch thick on top and sides

on the S-5, 2-inch thick top and sides on the S-7 and S-10; with a 3-inch bottom thickness on all models.

All seams in the corkboard are filled with Hydrolene. Waterproof paper is then applied over the corkboard as added

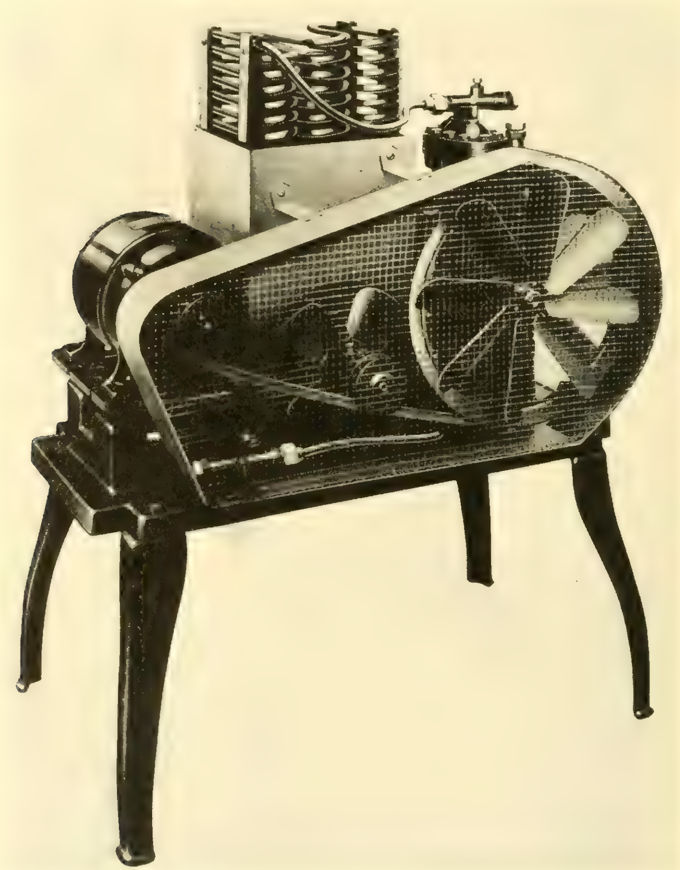


FIG. 137.—SERVEL SEMI-COMMERCIAL REFRIGERATING UNIT.

seal against air leaks. An air space of ¼-inch to ½-inch is used between the outer metal shell and the insulation surrounding the liner.

The semi-commercial machines are shown in Figs. 137

and 138. The 15-A is particularly adapted for ice cream cabinets and low temperature work. The rated capacity of the

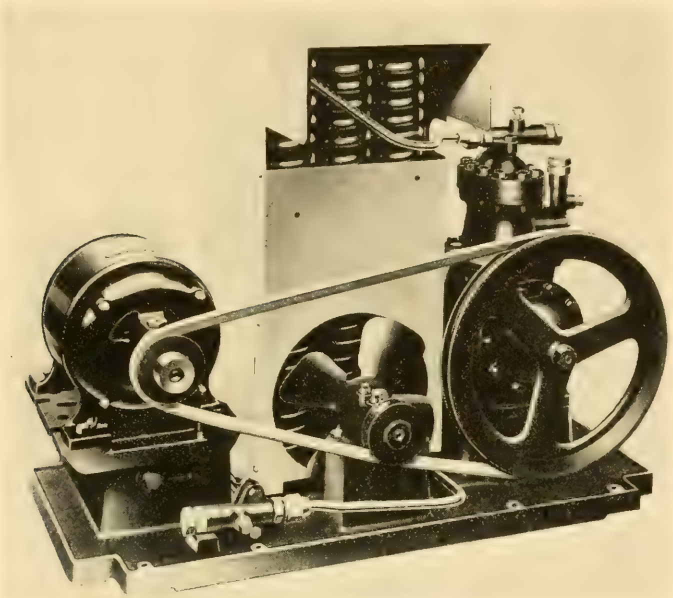


FIG. 138.—SERVEL SEMI-COMMERCIAL REFRIGERATING UNIT.

15-A is 350 lbs. The 18-A has a rated capacity of 300 lbs., and is used on large household or small commercial boxes.

Socold.—Fig. 139 shows the compressor unit used in the electric refrigerator manufactured by the Socold Refrigerating Corporation of Boston, Massachusetts. The refrigerant used is sulphur dioxide.

The compressor has two vertical cylinders. The pistons are driven by connecting rods operated by a walking beam. The drive shaft oscillates on an arc of 12 to 15 degrees each side of center at slow speed. A plate of special metal seals against a shoulder on this shaft. Thus the wear on the packing is very slight. The discharge valves are in the cylinder head and are made of three monel discs. The suction valves are single parts in the cylinder walls.

The condenser consists of a coil of one tube mounted on the same base with the compressor. Forced air cooling is obtained by a fan in front of the motor and in the compressor drive wheel.

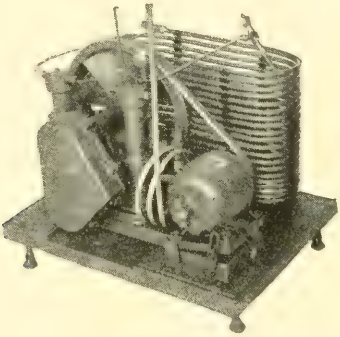


FIG 139.—SOCOLD REFRIGERATING UNIT.

FIG. 140.—SOCOLD FROST UNIT OF HEAVY SEMI-STEEL CONSTRUCTION.

Fig. 140 shows the frost unit which is of heavy galvanized semi-steel construction and operates on the direct expansion system. An expansion valve of single construction is used to reduce the pressure of the liquid refrigerant.

FIG. 141.—SOCOLD TYPICAL STEEL CABINET.

A Mercoid thermostat is used for temperature control. It is responsive to the temperature of the frost unit and not by temperature of the food compartments, which issues a constant supply of ice cubes without making seasonal adjustments necessary. The thermostat is set to maintain a temperature in the frost unit of from 20 to 24 degrees F. This

produces a temperature of from 45 to 50 degrees F. in the food compartment.

Fig. 141 and 142 show typical steel cabinets.

The construction provides one air and moisture tight steel

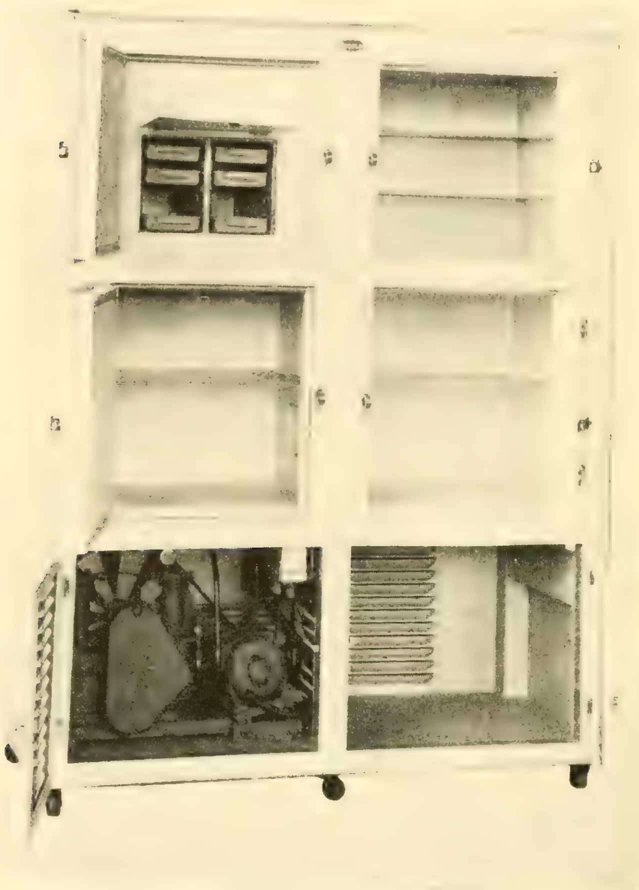


FIG. 142.—SOCOLD STEEL CABINET SHOWING REFRIGERATING AND FROST UNITS INSTALLED.

case inside another which will not permit the penetration of moisture and odors into the insulation.

Balsam-wool is used to insulate the cabinets. This material is manufactured from the fibers of northern coniferous woods. The process is somewhat similar to that employed in

pulp making, as the wood is first reduced by mechanical means and then chemically treated so the wood fibers are separated from one another. The individual fibers are fine, hairlike, hollow tubes, and at this stage are saturated with chemicals that render them non-inflammable and proof against decay. These fibers are handled by air and felted into a fleecy mat bound together with cement. An important feature of this mat is that its fibers extend in all three cubical dimensions, with the result that the blanket is remarkably light in weight and contains millions of dead-air cells.

To increase the mechanical strength of the fibrous blanket, a layer of water-proofed Kraft paper is cemented to each side of the blanket with asphalt. This method of applying the liner does away with stitching and leaves the surface of the material impervious to water and air.

The cold storage type of balsam-wool is particularly adapted for these small boxes because it is easily fitted in around the corners, is odorless either wet or dry, and will not support mildew or mold. A complete line of cabinets in porcelain or white baked enamel are manufactured.

Universal Refrigerating Machine.—Fig. 143 shows the household compressor unit manufactured by the Universal Ice Machine Company of Detroit.

The refrigerant used is ammonia. A ½ hp. motor drives the compressor by means of a "V" type leather belt and idler pulley. The compressor has a special type aluminum piston, designed to assure good lubrication and eliminate wear on the sides of the cylinders.

Disc plate suction and discharge valves are used. These are located in the head of the compressor and are easily accessible. The cylinder head is water jacketed. Metallic packing is used on the compressor crankshaft. The condenser is made of a double spiral coil with welded ends. Water flows through the inner coil.

Utility Refrigerating Unit.—Fig. 144 shows the mechanical unit used in the Utility Electric Refrigerator which is manufactured at Adrian, Michigan by the Utility Compressor Company. It is reported this company is now out of business.

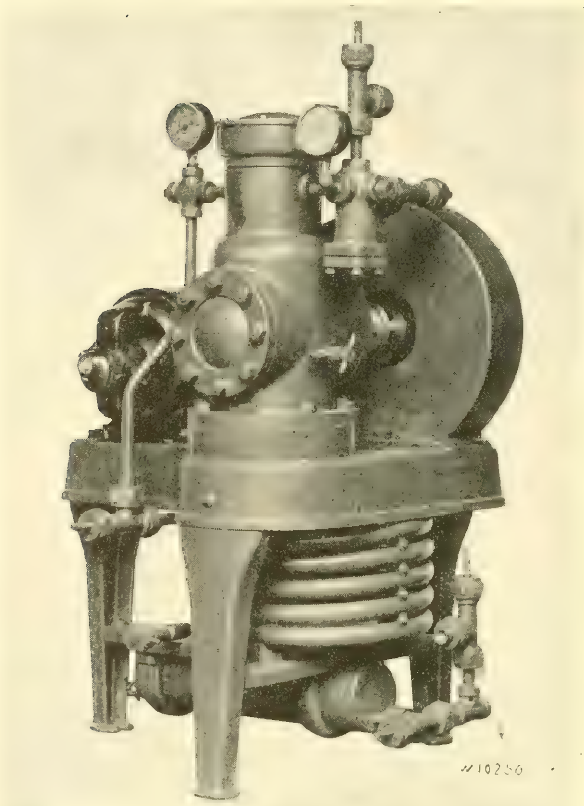


FIG. 143. UNIVERSAL REFRIGERATING MACHINE.

The electric motor and pump are enclosed in the dome at the right, hermetically sealed. This eliminates a packing gland for the shaft of the compressor.

The thermostat and the cooling coils, which absorb the heat from the atmosphere in the refrigerator are situated in the chamber at the left.

The condenser is of the radiator type and is located behind the dome and coil chamber. This condenser is air-cooled. The complete mechanical unit is interchangeable and easily removed from the cabinet.

In case service is required, it is claimed that the complete mechanical unit can be removed and another put in place in

fifteen minutes. This eliminates the need of mechanics working on repairs in the home. The small door is for the ice freezing chamber.

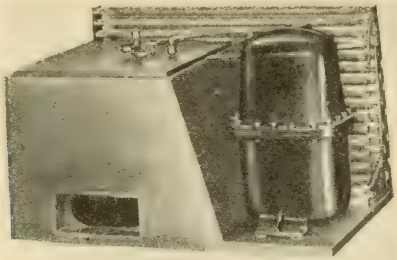


FIG. 144.—UTILITY REFRIGERATING UNIT.

The mechanical unit is placed in the upper part of a special cabinet. The cabinets are of white porcelain or natural wood exteriors. A one-piece porcelain lining is used. The cabinets are seventy inches high, thirty-eight inches wide, and twenty-three inches deep.

Ward. — Fig. 145 shows the condensing system of the household refrigerating machine made by the Ward Electric Refrigerator Corporation of Buchanan, Michigan.

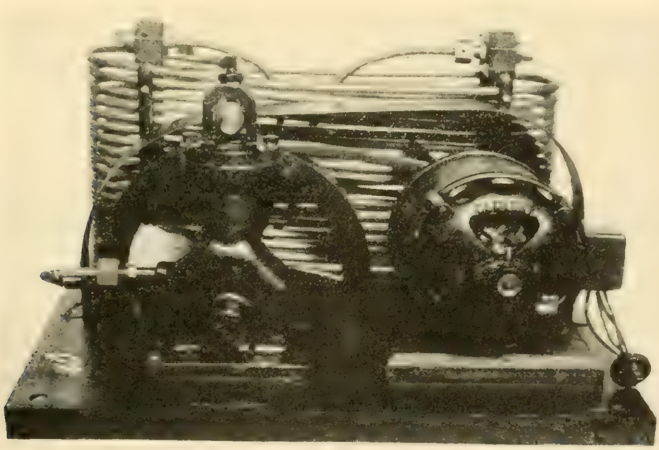


FIG. 145.—WARD HOUSEHOLD REFRIGERATING SYSTEM.

A $\frac{1}{6}$ hp. motor drives the compressor by means of a "V" type belt. The condenser consists of a coil of copper tubing. Air is forced over the condenser by a fan on the motor shaft.

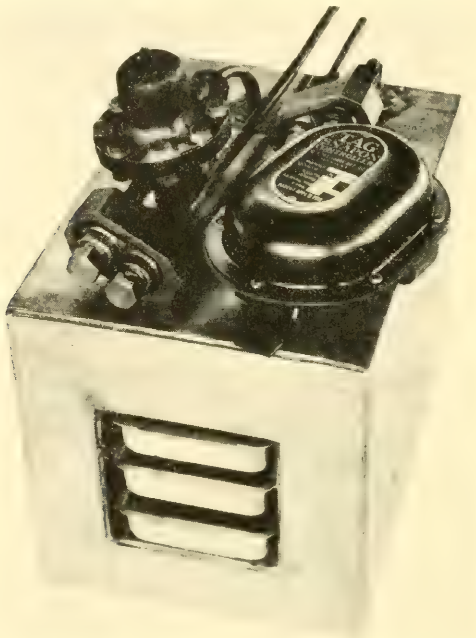


FIG. 146. WARD EVAPORATING SYSTEM.

Fig. 146 shows a typical evaporating system consisting of a brine tank, expansion valve and necessary connections. The thermostat control is mounted on the brine tank.

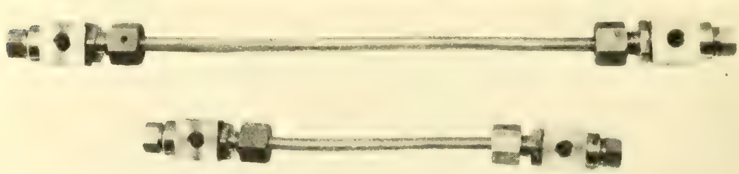


FIG. 147.—SHOWING SPLIT-VALVE CONNECTIONS, WARD REFRIGERATING SYSTEM.

The system is connected together by means of tubing containing split-valves on each end as in Fig. 147. This arrange-

ment eliminates the need to dehydrate, pull a vacuum or charge the machine when making an installation. The valves on each end of the tubing are shut off when charged at the factory and after dealer has connected up same with machine, they are then turned on by a ratchet wrench which operates on the end of each valve and thus the dealer does not lose the charge when installing unit.

FIG. 148.—WARD STEEL HOUSEHOLD CABINET.

One of the cabinets is shown in Fig. 148. The cabinet has a steel exterior and is insulated with corkboard. Various sizes and types of cabinets can be supplied.

Warner.—Fig. 149 and 150 show compressor units made by the Warner Stacold Corporation of Ottawa, Kansas.

Air-cooled sulphur dioxide compressors are made in the

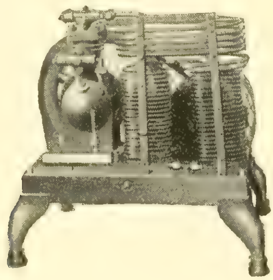


FIG. 149. WARNER STACOLD COMPRESSOR UNIT.

following sizes: 1-cylinder compressors driven by 1/6 and 1/4 hp. motors; 2-cylinder compressors driven by 1/4 and 1/3 hp. motors; 3-cylinder compressors driven by 1/2, 3/4 and 1 hp. motors.

These compressors are of the slow speed reciprocating type. A special "V" belt is used. The compressors have crank shafts which operate with less friction than eccentrics.

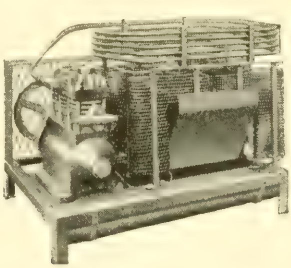


FIG. 150. WARNER STACOLD COMPRESSOR UNIT.

Ground removable cylinder sleeves are used. The commercial compressors have pistons equipped with 4 rings.

A series of 8 sizes of cooling tanks are made suitable for the various refrigerators.

Flooded type cooling coils are also made. These coils are used in apartment houses and commercial installations where

it is necessary to have more than one cooling coil connected to one compressor.

Metal cabinets are manufactured from 4.6 to 10.5 cubic feet food storage space. These cabinets are insulated with cork. The exterior has a lacquer finish. The interior is of white enamel or porcelain.

Welsbach.—This machine, Fig. 151, is manufactured by the Welsbach Company at Gloucester, N. J.

The refrigerant used is "Alcozol," which has been developed in the Welsbach chemical laboratories. "Welcolub,"

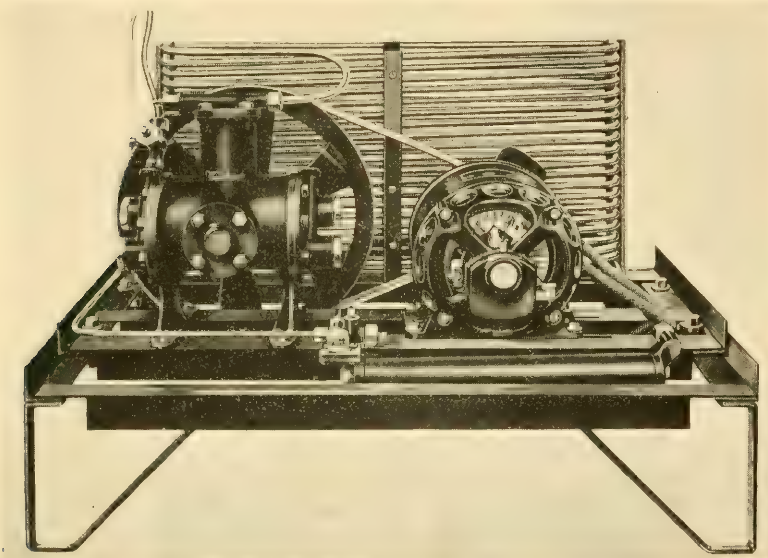


FIG. 151.—WELSBACH COMPRESSOR UNIT.

another product of the Welsbach laboratories, is used as the lubricant.

The compressor is of the horizontal, double acting type. The compressor cylinder has a bore of 3 inches, with a stroke of 1 inch. It operates at low speed—280 revolutions per minute. In normal operation in a 90° F. room the condensing pressure is 20 to 25 lbs., while the suction pressure is a vacuum.

General Electric and Century ¼ hp. motors are used, operating at 1750 revolutions per minute, with an average

connected load of 210 watts. The motor drives the compressor by means of a rubber-fabric "V" type belt.

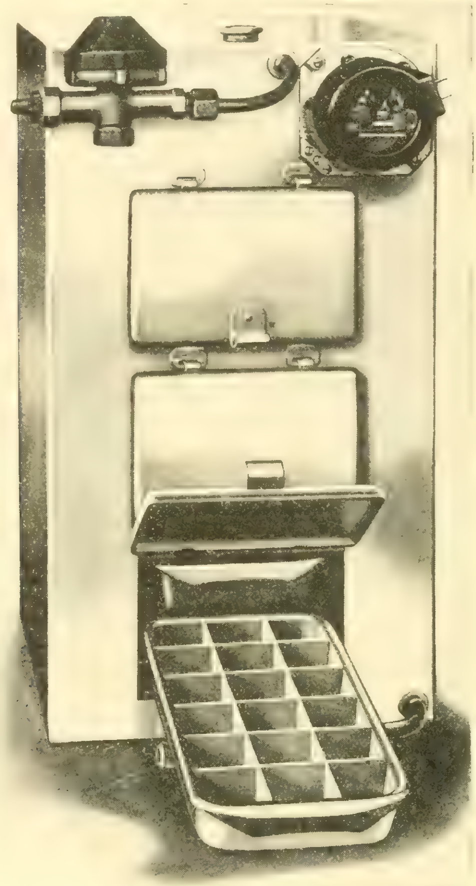


FIG. 152. WELSBACH FREEZING UNIT.

The condenser is made of ⅜-inch copper tubing. Forced air cooling is obtained by means of a two-blade fan on a motor pulley, and fan blades in the compressor pulley. The condenser supplies liquid refrigerant to a receiver of sufficient size to hold the entire charge.

Fig. 152 shows the freezing unit made of tinned copper, containing a non-freezing solution of glycerine and water.

The expansion coils are made of ⅜-inch copper tubing, pan cake winding. A downward pitch in the evaporator permits the drainage of circulated lubricant back to the compressor.

An expansion valve is used and automatically maintains a predetermined vacuum, regardless of the condensing pressure.

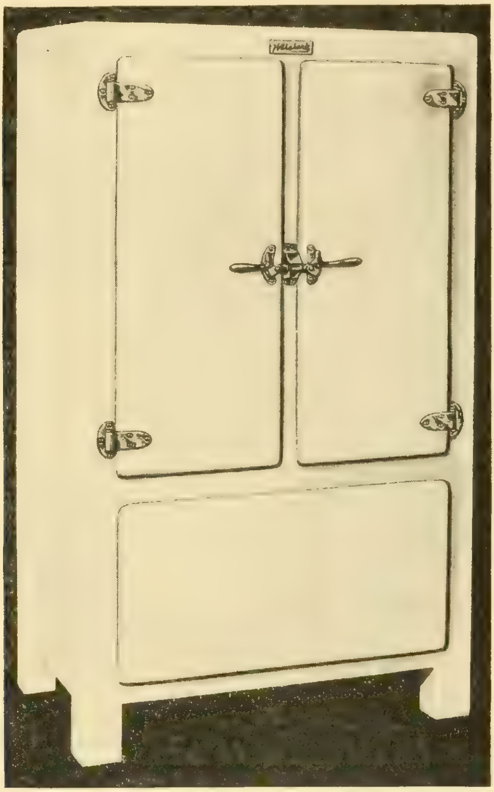


FIG. 153. WELSBACH STEEL CABINET.

The automatic temperature control consists of a mercury switch mounted on a bi-metallic coil sealed in a bakelite case. The control is mounted on the upper right-hand corner of the cooling tank.

Fig. 153 shows a typical steel cabinet as manufactured by the Welsbach Company. Fig. 154 shows a typical hardwood cabinet made of 5-ply laminated wood, using flush panel con-

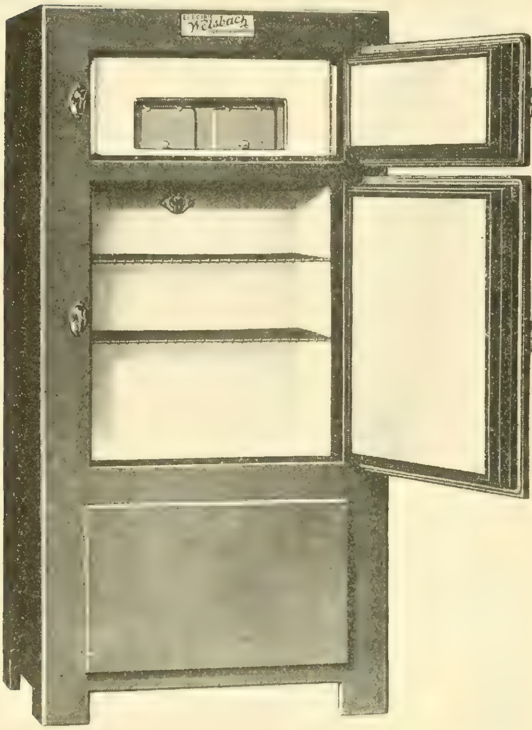


FIG. 154.—WELSBACH HARDWOOD CABINET.

struction. Both the steel and wood cabinets are supplied in various models. The dimensions, food storage space, number of trays and number of ice cubes vary with different models.

Whitehead.—Fig. 155 shows the compressor unit used with the household refrigerating machine manufactured by the Whitehead Refrigeration Company of Detroit, Michigan.

The compressor is of the reciprocating type. It is connected directly to the motor shaft and operates at motor speed, thus eliminating belts or gears. A flexible coupling is used to connect the motor and compressor shafts.

The condenser is made of finned tubing and is cooled by forced air. The fan is mounted on the compressor motor shaft.

Methyl chloride is used as the refrigerant. The receiver

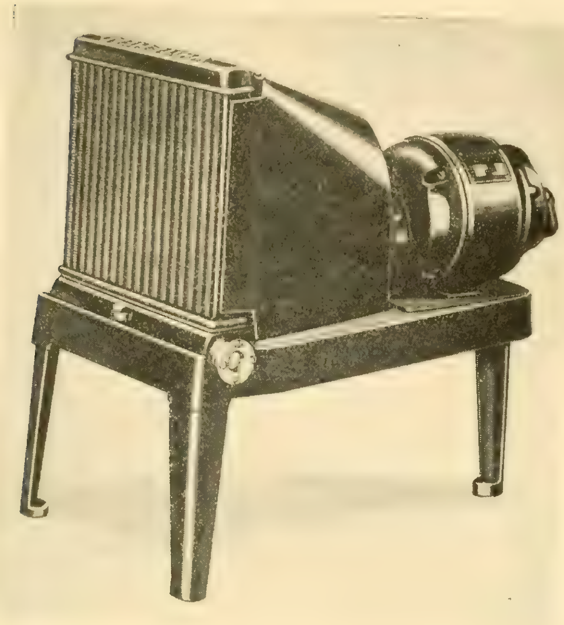


FIG. 155.—WHITEHEAD COMPRESSOR UNIT.

FIG. 156.—WHITEHEAD COOLING UNIT.

contains a visible gauge showing the amount of refrigerant contained in the receiver.

The temperature control is of the mercury tube type.

Fig. 156 shows a typical cooling unit. This is made in five sizes as follows:

Tank Size	Width	Depth	Height	Ice Box Capacity	Maximum Cube Capacity per Freezing
1	10 in.	11 in.	10 in.	5-7 cu. ft.	96
2	10 in.	11 in.	13 in.	8-10 cu. ft.	96
3	10 in.	11 in.	16 in.	11-15 cu. ft.	144
4	11 in.	11 in.	19 in.	16-20 cu. ft.	144
5	11 in.	11 in.	23 in.	20-30 cu. ft.	192

Williams Simplex.—An air cooled refrigerating machine was developed for household use called the Williams Simplex. Ethyl chloride is used as the refrigerant.

The compressor is of the rotary type, directly connected to the motor shaft without employment of intermediary gearing or belting. The compressor has a volumetric efficiency ranging from 82 per cent to 85 per cent, and a mechanical efficiency comparing favorably with the best reciprocating types of many times greater capacity.

A ground steel collar is used to seal the drive shaft. This collar is self-aligning and automatically takes up wear, as it is attached to the compressor by means of a corrugated metallic tube. A spring, assisted by the condensing pressure, holds these members in firm contact. This forms a tight joint, which will run indefinitely without a tendency to wear or break down.

The compressor is mounted integrally with and supported by the motor. Positive pressure feed of lubricant is maintained to all moving elements of the compressor while in operation.

The compressor and condenser are cooled entirely by maintaining a current of air over their surfaces. The air is circulated by means of a Sirocco type of blower mounted between the motor and the compressor, the blower casing forming the supporting bracket for the compressor.

The air is first drawn through the condenser chamber which contains a continuous coil of copper tubing into which

the refrigerant vapor is compressed, taking up the latent heat of vaporization; it then passes over the heat radiating fins of the compressor, from which it discharges through a flue extending through the top of the machine cover. Air is also simultaneously drawn from the opposite direction through and around the motor and discharged from the fan as above described.

The so-called flooded system is employed, in which the expansion or cooling coils are filled with liquid refrigerant. These coils connect into a vertical header from the top of which the vaporized refrigerant is drawn. This vapor, after being liquefied in the condenser, is discharged into a small chamber fitted with a float valve, which permits it to feed back into the expansion coils at the same rate at which it is being condensed.

These features are important, in that the radiating surfaces of the cooling coil have a much higher heat transmitting capacity when full of liquid. The ratio to the usual method of gas expansion at constant pressure is about 1.56 to 1.

A still more important advantage is that the expansion pressure is automatically varied to maintain constant balance between the compressor capacity and the radiating surfaces as the temperature changes. This provides maximum efficiency operating conditions throughout any range of temperature, while in the usual gas expansion method the pressure is necessarily set and held for the lowest temperature required, which is always the condition of lowest efficiency.

The machine is controlled by means of a thermostat, arranged to operate responsive to the temperature of the brine surrounding the coils in the brine tank. The switching apparatus and its actuating motor are located on the machine base, while the bulb of the instrument only is located in the tank. The advantage of placing the thermostat bulb in the brine tank is due to the fact that the maximum temperature change occurs in the brine.

A safety pressure switch is also used, which is operated directly responsive to the refrigerant condensing pressure.

The machine has a capacity when operating at 15° F. of about 150 lbs. ice equivalent per 24 hours. The power con-

sumption, including motor losses, is from 190 to 200 watts with direct current, and from 260 to 300 watts with alternating current, the difference being due to the larger losses in the alternating current motor.

Zerozone.—The Zerozone Household Electrical Refrigerating Unit is manufactured by the Iron Mountain Company of Chicago, Illinois.

This is an air-cooled compressor type unit using a cooling unit of the indirect type. The refrigerant used is sulphur dioxide.

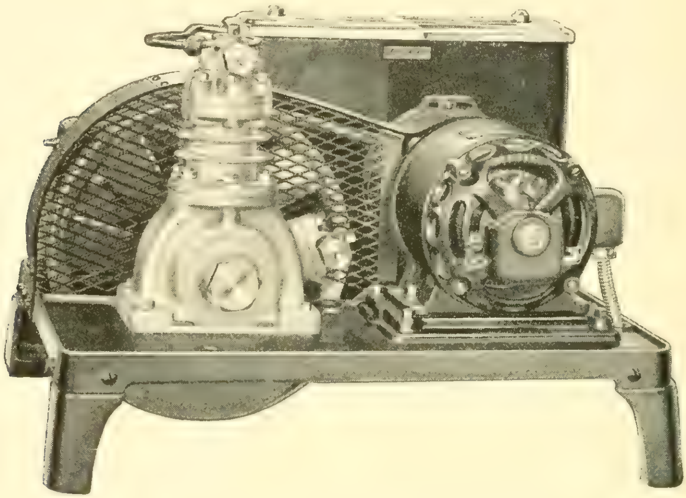


FIG. 157.—ZEROZONE ELECTRICAL REFRIGERATING UNIT.

The compressor unit consists of a one-cylinder reciprocating type compressor which is used on all well insulated refrigerators up to 20 cu. ft. and is shown in Fig. 157. The bore and stroke is 1¾ inch and the compressor operates at 330 r.p.m. The compressor is driven by a ¼ hp. repulsion induction electric motor by means of a "V" type belt.

A two cylinder type compressor is used on all refrigerators from 20 to 50 cu. ft. and is shown in Fig. 158. The bore and stroke is 1¾ inch and the compressor operates at 265 r.p.m. driven by a ⅓ hp. repulsion induction electric motor by means of a "V" type belt.

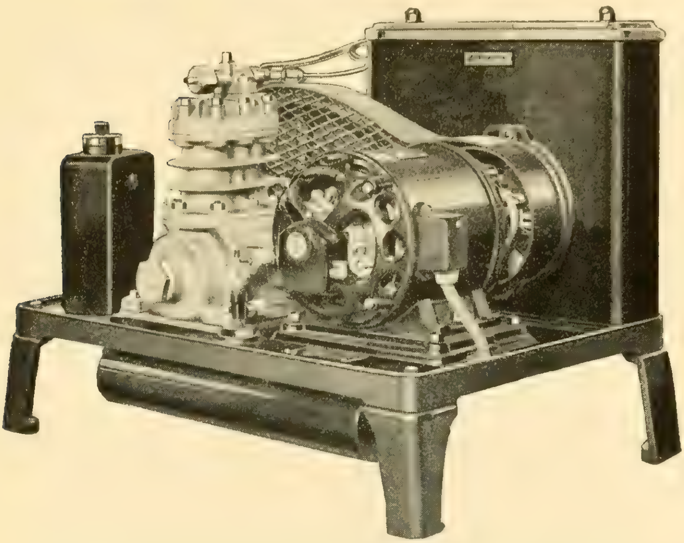


FIG. 158.—ZEROZONE TWO-CYLINDER TYPE COMPRESSOR.

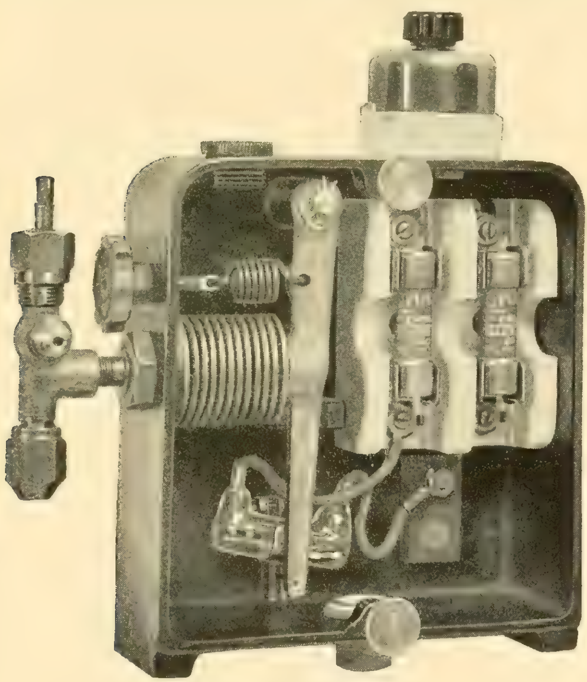


FIG. 159.—ZEROZONE AUTOMATIC CONTROL.

The condenser in each case is a double copper coil cooled by forced air by means of a fan attached to pulley end of the motor shaft.

The control used on the individual installation is an automatic thermostat, Fig. 159, and is responsive to the tempera-

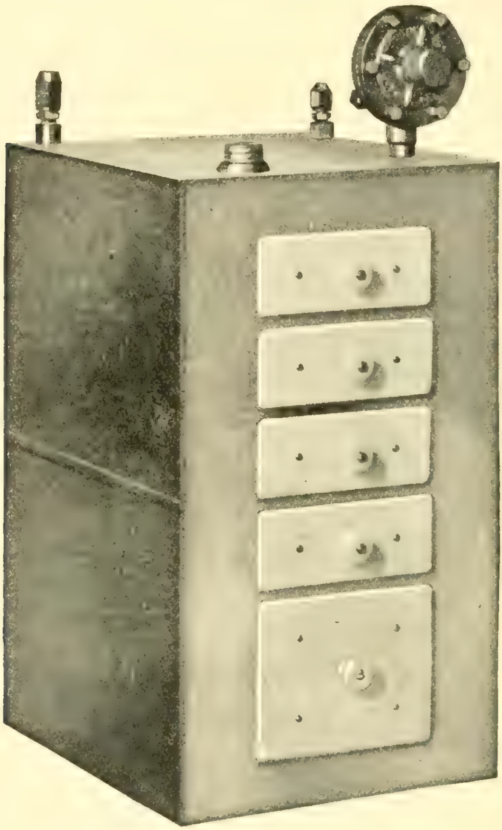


FIG. 160. ZEROZONE COOLING UNIT.

ture in the cooling unit. The thermostat tube in the cooling unit connects to a sylphon which operates a mercury tube switch, by means of a suitable lever mechanism.

The control used on the Multiple installation is of the low pressure type, and is responsive to the pressures in the low side of the refrigerant system. This low pressure control,

controls the operation of the compression unit itself, the temperature of each cooling unit in the multiple installation being controlled individually by a low side, thermostatic actuated valve, commonly referred to as a temperature governor.

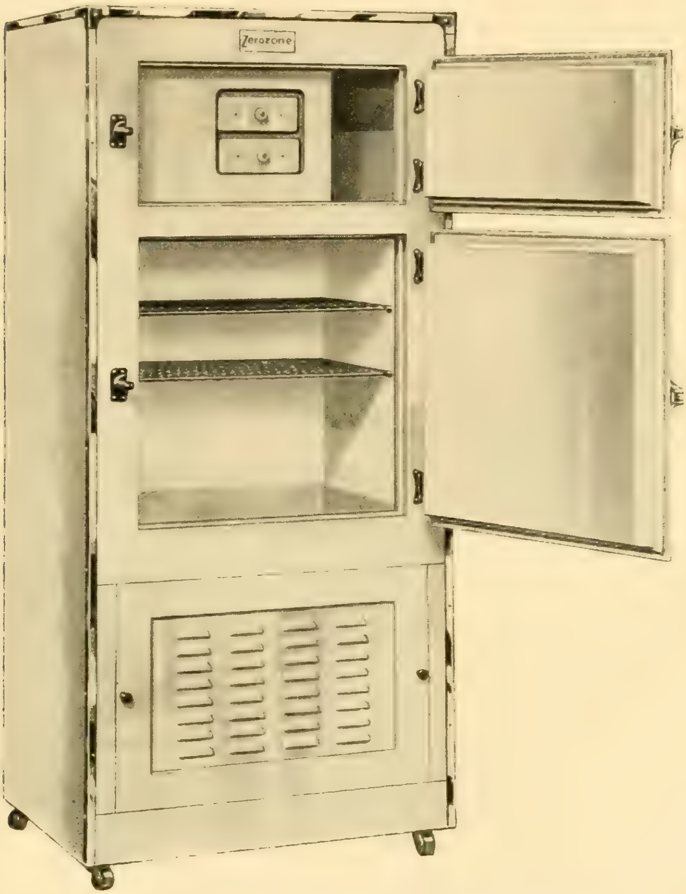


FIG. 161.—ZEROZONE SELF-CONTAINED METAL CABINET.

A diaphram type expansion valve is used to automatically meter the correct supply of liquid refrigerant to the expansion coils.

The cooling units are made of 20 ounce sheet copper, made in various sizes, one of which is shown in Fig. 160, and con-

tains $\frac{3}{8}$-inch copper tubing for the expansion coil. The non-freeze solution is calcium chloride.

Fig. 161 shows a typical self-contained cabinet, the exterior of which is metal, finished with white lacquer. Cork-board is used to insulate the walls and doors. The lining is of the one piece porcelain on steel type. The cabinets are made in various styles and sizes.

CHAPTER VIII

HOUSEHOLD REFRIGERATING MACHINES ABSORPTION TYPE

Household Absorption Refrigerating Machines.—In this chapter, attention will be given to the general types and charactertistic construction of a number of household absorption refrigerating machines.

Ice-O-Lator.—Fig. 162 shows an absorption type refrigerating machine manufactured by the Winchester Repeating Arms Company for the National Refrigerating Company at New Haven, Conn.

The "absorbent" which was the result of so many years of research by Prof. Keyes is the basis of the machine. Other absorbents have been known. Charcoal is an efficient absorbent and is frequently employed to absorb gases of various kinds. A good example is in gas masks. But charcoal cannot be employed in refrigeration because it is such a poor conductor of heat that no practical degree of efficiency can be obtained in the operation of a machine using it. You can get the gas into it well enough, but you can't get it out again without the expenditure of a prohibitive amount of energy. This absorbent combines the highest known absorbing qualities together with the quality of high heat conductivity.

Following are the qualities which the inventors set out to embody in their absorbent. They are the properties of an ideal material:

1. Cheapness and unlimited supply.
2. Should absorb at least 100 per cent of its own weight of refrigerant.

3. Should have a high heat conductivity in order to facilitate the removal of heat of absorption and also the application of heat for driving off the refrigerant.

4. Cellular, or porous structure, in order to present necessary working surface.

5. Stability. There should be no diminution of operating efficiency, or no disintegration or decomposition after continued use.

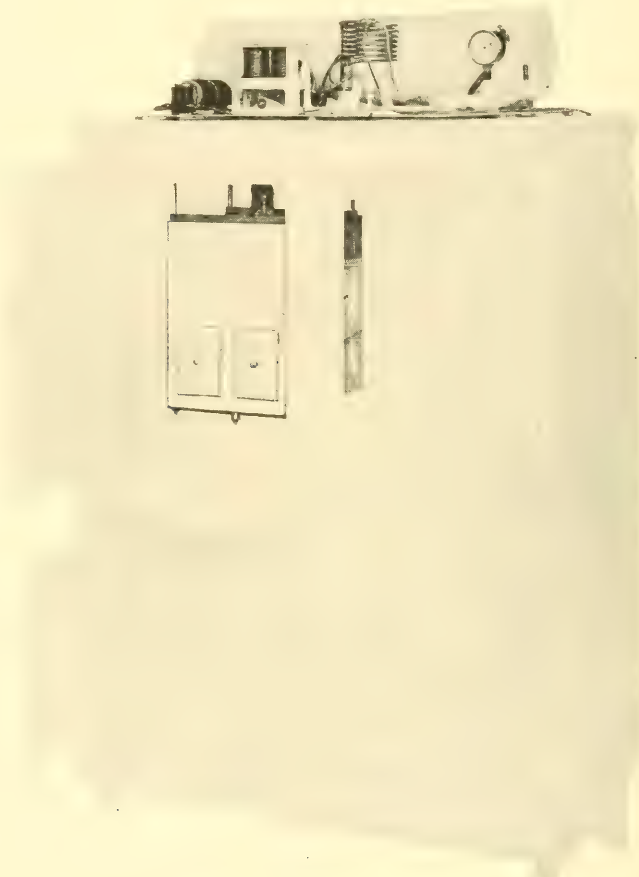


FIG. 162. NATIONAL REFRIGERATING MACHINE.

In three years of continuous operation, no sign of decreased efficiency has developed.

A brief comparison with water, the best known absorbent, forms a favorable basis for comparison. Water compels the

use of aqueous ammonia. This material is absolutely dry, making possible the use of pure anhydrous ammonia. Water absorbs 40 per cent of its own weight of ammonia. This material absorbs approximately 110 per cent of its own weight of ammonia gas and in addition loses its working charge on the application of about half the amount of heat necessary to drive the much smaller charge from water. Result—much less bulk and much more economical operation.

As the efficiency of the material has been steadily increased by constant scientific research since its discovery, there is considerable possibility that it may be still further increased.

The small household machine operates as follows: A steel tube is filled with a material which will absorb a large quantity of ammonia gas. When heat is applied the pressure is increased and the NH_3 gas is liberated and passes through a filter and check valve to the condenser. When the pressure reaches a point that corresponds to the temperature of the cooling water, condensation takes place and liquid NH_3 is delivered to the liquid valve float chamber. The purpose of this chamber is to insure complete condensation by the cooling water. The liquid NH_3 is then delivered through a small orifice and tube to the refrigerating chamber and coils. The heating continues until enough liquid NH_3 has collected in the refrigerating chamber and coils to make a contact by means of the float contacting mechanism at the top of the refrigerating chamber. When this contact is made the relay switching system is tipped to the opposite position, the heating circuit is broken, and the water is shifted by means of the valve from the condenser to the generator. As soon as the pressure over the material in the generator has dropped to the point which is less than the vapor pressure of the liquid ammonia in the refrigerating chamber and coils, boiling in this chamber commences and continues until all the liquid has evaporated. This evaporation may require from one hour to five hours depending upon the temperature in the refrigerator. When the temperature is high, the evaporation is very rapid and when it is low the boiling requires a much longer period of time. The temperature in the refrigerator, then is regulated by the rate of evaporation of the liquid. The brine tank maintains the

low temperature during the heat period when no refrigeration is taking place so that the temperature in the refrigerator is practically constant. When the entire quantity of liquid has evaporated a contact is made at the bottom of the refrigerating chamber which tips the relay to the heating position, the heating circuit is made, the water is shifted back to the condenser, and the cycle repeats.

Fig. 163 shows a diagramatic drawing of the gas-fired Ice-O-Lator. This model has electrical controls and is water-

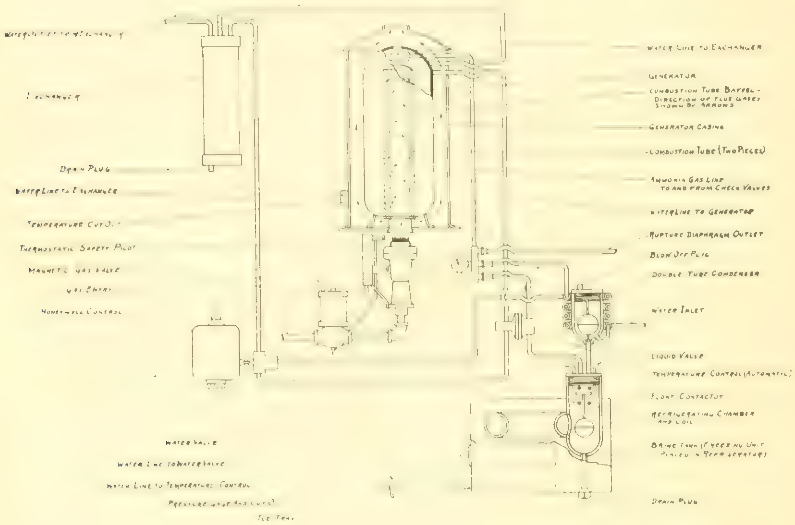


FIG. 163.—DIAGRAMMATIC DRAWING OF THE GAS-FIRED ICE-O-LATOR.

cooled. The unit is placed in the cellar or any convenient place outside of the refrigerator cabinet.

The following information concerning the cost of operating this unit is of interest.

Illuminating or coal gas delivers 520 B.t.u. per cubic foot and natural gas an average of 1100 B.t.u. per cubic foot. One kw-hr. of electricity at 110 volts delivers 3415 B.t.u. Taking coal gas for comparison, 6.56 cu. ft. of gas is equivalent to one kw-hr. of electricity for heating purposes.

The cost of gas per 1000 cu ft. ranges from $0.40 to $1.50 in various localities. Many cities have a rate under $1.00.

Natural gas, with about double the B.t.u. of coal gas, can be purchased for as low as $0.40 per 1000 cu. ft. in some localities As against this, the cost of electricity averages about $0.55 per kw-hr.

Heat for heat, the difference will readily be seen. At $1.00 per thousand cu. ft. for coal gas the same number of B.t.u. can be obtained for three-fifths of a cent as from five and one-half cents' worth of electricity at the above rate.

The following table shows the approximate cost of operation, for the equivalent of 100 lbs. of ice refrigeration, of a machine using gas at the various rates.

Cost of Gas Per 1000 Cu. Ft.	Cost Per 100 Lbs. of Refrigeration
$0.40	$0.05
.80	.10
1.00	.125
1.50	.187
2.00	.25
2.80	.35

It will probably have been observed that the small household machine is cyclic and subject to peaks. Whereas this has not proven an objection in any of the machines at present in operation, still in the event that continuous refrigeration should be desired to meet some special conditions, such can easily be obtained by the use of two generators, one absorbing while the other distills.

Keith.—Fig. 164 shows an ammonia absorption type household refrigerating machine made by the Keith Electric Refrigerator Division of the Canada Wire and Cable Company, Ltd., at Leaside, Ontario, Canada.

Referring to Fig. 164, which shows the unit in the cooling position, on the left hand side in the generator, is about two quarts of ordinary "ammonia" as used in the home. Within the tank there is also a small electric heater. When the heater is started the gas is driven out of the water, just as you can see gas or bubbles of air driven out of the water in your tea kettle as it begins to boil. This gas is not very warm, as ammonia is easily driven off, and when it flows over into the pipes shown on the right hand of the illustration, it is chilled by a trickle of cold water which is flowing over the pipes of

the condenser. When it is chilled, the gas is deposited on the inside of the condenser, about the same as dew is deposited by the chill of the morning air. This deposit is pure liquid ammonia.

When the condenser is nearly full of pure liquid ammonia, in approximately one hour's time, it begins to weigh more than the generator, and swings down, pulling the generator up and shutting off the electric heater. Almost immediately the pure liquid ammonia begins to evaporate and chills the

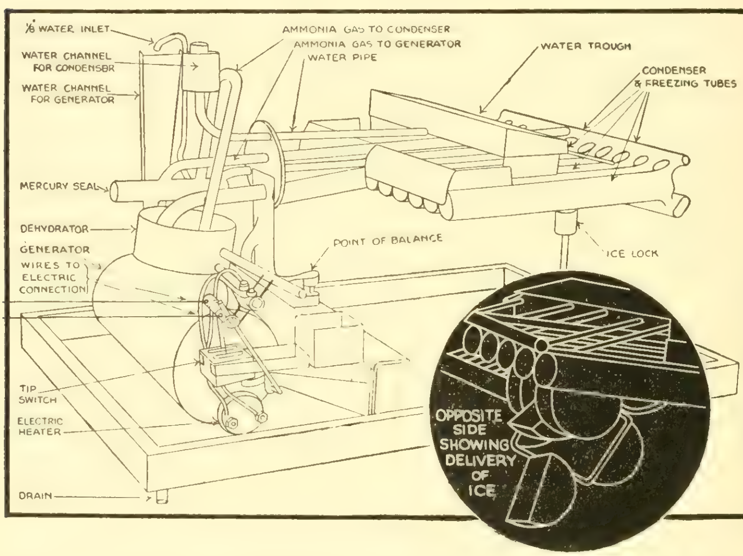


FIG. 164. KEITH AMMONIA ABSORPTION TYPE REFRIGERATING MACHINE.

pipes to approximately zero temperature. This chills the surrounding air, which flows down into the food compartment of the refrigerator.

As the pure liquid ammonia evaporates, it flows back as a gas into the tank of water, where it is once more quickly absorbed. As soon as all the ammonia is returned to the generator, the pipes of the condenser naturally become lighter and the tank (or generator) heavier, and the unit gently tilts back to the original position, the electric heater starts and the operation commences all over again.

The operation, as has been explained is purely automatic, requiring no attention and maintains an even cold temperature at all times, ideal for the preservation of food. The amount of electrical energy consumed averages about 3½ kilowatt hours per day for continuous operation, depending on the weather and other conditions.

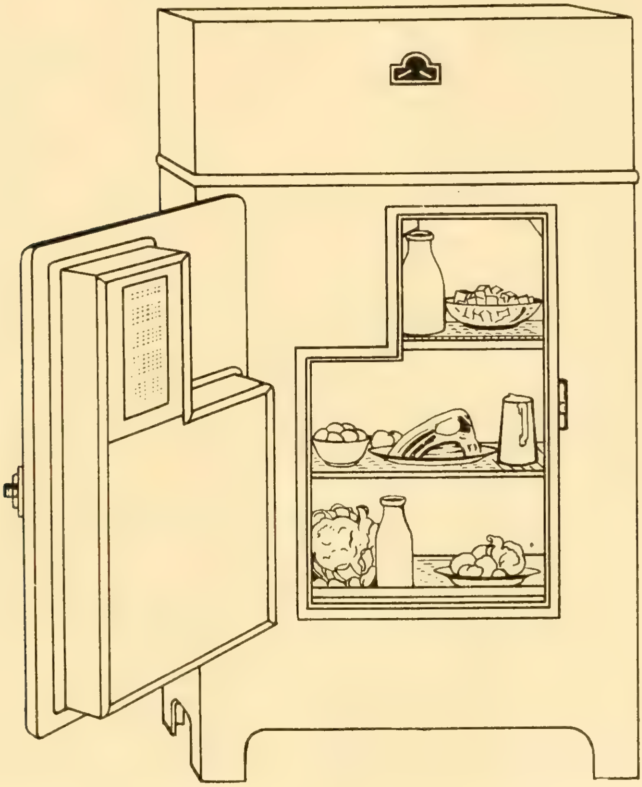


FIG. 165. KEITH REFRIGERATING UNIT INSTALLED IN COMPARTMENT ON CABINET.

Heater—900 watt resistance coil, porcelain core, inserted in steel tube through generator.

Ice lock—Holds the condenser down until all ammonia is in the generator. Is released by temperature rising above freezing point.

Tip switch—A safety device to disconnect the electricity should the water be shut off.

Mercury seal—Contains mercury, which runs to lowest point with the tilting of the unit opening and closing the ammonia pipe to condenser.

Dehydrator—Eliminates water vapor from ammonia gas as it rises to the condenser.

The cabinet, Fig. 165, shows a complete self-contained unit with the machine in the compartment at the top.

Master.—An absorption machine of simple design is made by the Master Domestic Refrigerating Company, Inc., at Flushing, N. Y. It comprises a cylindrical generator, water cooled condenser and evaporator, connected by a single pipe to form the complete machine. It is made entirely from steel pipe and sheet steel.

Only water and ammonia are used as the means of producing refrigeration. These substances are charged in the generator in the correct proportions. Ammonia in the form of gas is released by applying heat to the generator. The gas is then cooled and liquefied in the condenser from which it flows by gravity to the evaporator in the cooling compartment of the refrigerator. By the subsequent cooling of the generator a reduction in the pressure is produced and the ammonia slowly evaporates thus producing the required refrigeration. The gas is re-absorbed by the cooled water in the generator. When the evaporation of the ammonia is practically completed a new cycle automatically begins.

The necessary reduction of the pressure is attained solely by the cooling of the generator, no check, float, or expansion valve, restricted orifice or other device is used in the machine and the pressure is always the same at any given time in all parts of the machine. The generator, condenser and evaporator freely communicate with each other at all times with pipe of full orifice.

The machine requires no attention as it is completely automatic. The automatic control consists of a power element actuated by the temperature of the generator, and a further power element which is placed in contact with the evaporator. The cooperation of these two power elements, by means of a simple mechanical principle, which is novel in its application to this machine, regulates and establishes the heating and cool-

ing periods and assures the proper and continual functioning of the machine in a simple and positive maner.

Should for any reason the supply of water to the condenser be interrupted, the heating means is automatically cut off. Simple and effective means are provided for automatically returning to the generator any water which may be carried over by the ammonia gas to the evaporator.

The machine and refrigerator are built as a complete self-contained unit, but, if desired, the machine may be installed outside of the refrigerator. Defrosting of the evaporator is automatic. Provision is made for an ample supply of ice cubes for table use.

The present machine is used to cool refrigerators of any size up to eight cubic feet inside capacity.

The Electrolux Servel. — The first practical continuous operating absorption refrigerating machine was made about the year 1860 by a Frenchman named Carre. His apparatus consisted first of a source of heat, generator, condenser cooling water, expansion valves, evaporator, absorber and pump. The heat liberated the ammonia gas from the aqua ammonia, so called "rich solution or strong liquid" leaving a weak liquid or water in the generator. The gas passing to the condenser is cooled off by the cooling water and condensed into a liquid. The liquid ammonia flows through the throttle or expansion valve into the evaporator, where the liquid ammonia is vaporized into a gas. During the evaporation heat is withdrawn from the surroundings, and thus cold is produced. The cold vapor passes into the absorber where it is sprayed by weak liquid from the generator. By the expulsion of the ammonia from the aqua-ammonia solution in the generator, the remaining liquid is to a large extent water. This poor solution being exposed to the high pressure passes through an expansion valve into the absorber. In this way the poor solution, meeting the ammonia vapors, absorbs them, so that in the bottom of the absorber a mixture collects as a "rich or strong solution." This solution is continually forced into the generator by the pump, which is operated by outside mechanical forces. A line drawn from the expansion valves through the pump

separates the machine into a high pressure side and a low pressure side.

In the apparatus of Carre's there are two cycles. The ammonia circulates from the generator through the condenser, the vaporizer and the absorber back to the generator. It therefore passes through all four receptacles. The water circulates from the generator to the absorber and vice versa. The water therefore only passes through these two receptacles.

The Carre machine was built in great numbers, being used in breweries, distilleries and similar plants where large amounts of heat vapor was available for which at that time no particular use was made.

However as the steam technique further developed and afforded numerous uses for exhaust steam for other purposes, the employment of the absorption machine became less and less. This was further augmented by the high efficiency of the newly developed compressor system. Mechanical difficulties also played a role as with small units as were used, the expansion valves were necessarily small and the orifice was continually clogging up with dirt; then too the pumps were a source of constant maintenance and had to be operated by auxiliary power, independent of this source of heat used in evaporating the aqua-ammonia.

There therefore arose a demand for small continually operating absorption machines, from which the above said defects of the machine of Carre were eliminated, said machines to have neither expansion valves nor pump, but which could be operated merely by the heat supply.

This was the aim of Geppert. In order to reach this aim he dispensed with the difference of the total pressure for the purpose of vaporization. With the same total pressure in the entire apparatus he tried to effect the vaporization necessary for refrigeration, as well as the reuniting of the ammonia gases with the water, and returning the mixture to the boiler without a pump or other mechanical energy. To this end, Geppert, in adition to the cooling medium (ammonia) and the absorbing liquid (water) used in the vaporizer a third medium, to wit, a gas, in the presence of which according to physical laws (due to the difference of so called partial pressures of

the gases) liquid ammonia evaporates without a drop of the total pressure being required.

In the year 1899, Geppert built such an apparatus. In the boiler the ammonia gas is expelled as in the Carre machine. After being liquified in the condenser the liquid ammonia flows through a conduit into the upper pan of the evaporator. In this liquid is immersed a porous material which is so placed as to extend over the rim of the inner opening and extending completely under the pan. The porous material with its large exposed surface facilitates the evaporation of ammonia in the presence of the second gas contained in the receptacle. The second gas used by Geppert was air. At a slight distance below the porous pad on the bottom of the upper pan is a bath of poor solution, which flows from the boiler, being cooled by passing through a cooler on its way to the absorber. It will thus be seen that Geppert combined the evaporator and absorber into one vessel. The ammonia gases resulting from the evaporation at the surface of the porous material diffuses downward through the second gas filling the receptacle and is then absorbed by the absorption liquid. The rich liquid then flows back to the generator where by the application of heat ammonia gas is again expelled.

The machine of Geppert is based on the theoretically correct idea that a pressure drop requiring throttle valves and pump becomes unnecessary in a refrigerating machine, if in the evaporator the liquid ammonia meets with a gas in whose presence the ammonia evaporates. The machine as designed refused to work and Geppert has himself seen the drawbacks of a design in which the ammonia has to diffuse through a thick layer of inert gas. This is apparent from other drawings later on submitted by him. In the next design he reduced the thickness of this layer and employed a fan to aid the evaporation, by having the lower parts of the fan blades dip into the liquid. By doing this he was able to further separate the cold evaporator from the warm absorber thereby reducing the refrigerating losses. The fan had to be operated by a motor and this was one of the pieces of equipment that Geppert had set out to eliminate. Another reason why the machine proved impractical was that when the ammonia vapors are absorbed

by water heat is liberated. The absorber therefore acts as a heater. Cooling water had to be provided in pipes located within the absorber. Notwithstanding this, heat liberated during the absorption rose into the evaporator space above, thus either entirely or partially counteracting the heat withdrawn from the surroundings by the evaporation of the ammonia. Effective refrigeration therefore cannot take place, or only in a very limited degree.

In the year 1901, Geppert attempted another design which was somewhat of an improvement over the two previous models. He still maintained the combined vaporizer and absorber. The receptacle was provided with a double wall, cooling water circulating in its hollow space. Into the receptacle is inserted a cylinder at a very slight distance from the inner face of the double wall of the receptacle. The cylinder contains salt water. The cylinder does not extend to the bottom of the receptacle. Into the free space flows from the boiler "poor solution." The operation was as follows:

The ammonia which had become expelled from the rich solution and liquified in the condenser flows through a small pipe to the outer surface of the wall of the cylinder, which wall is covered with porous material. There the ammonia becomes distributed and evaporates. Heat is therefore withdrawn from the salt water contained in the receptacle and cold is produced. The produced ammonia vapors diffuse through the small intermediate space to the opposite inner surface of the double wall of the receptacle. This surface is sprayed by poor solution which by means of a small pump is continually pumped through the pipes from the lower portion of the receptacle upwards into the space between the double wall of the receptacle and the cylinder. The surface on which the poor solution flows down is cooled by the cooling water in the hollow space of the double wall. As the poor solution flows down, it absorbs the ammonia gases which are diffused in its direction from the opposite surface and thereby is enriched with ammonia. Thus the outer surface of the cylinder acts as a vaporizer, and the inner surface of the wall of the receptacle as an absorber. The absorber therefore, is, not like in his previous patent, below the vaporizer, but the absorber

and vaporizer located in one and the same vessel, at the same level side by side. It will be noted that Geppert had to take recourse to the pump, which is one of the pieces of equipment he started out to eliminate. While he succeeded in producing cold, with his last design, the efficiency was small—also he failed to attain one of his objects, namely to eliminate the pump.

After Geppert failed, no trace can be formed of any practical and useful small refrigerating machine of any importance, operating according to the absorption principle in a continuous manner, until the year 1922 when two students, Baltzar Carl Von Platen and Carl George Munters of the Royal Swedish Institute of Technology developed and designed a working model which dispensed with all moving and mechanical parts.

This unit was later developed by the Electrolux Aktiebolaget in Europe and the Electrolux Servel Corporation in the United States, so that today we have a workable and saleable refrigerating unit that is indeed marvelous. In order to develop the present day product a large laboratory for research work was established in Stockholm, Sweden, and in Brooklyn, New York. In these laboratories developments and experiments are taking place so as to develop new types for further commercial applications. How well this unit with refrigerator has been developed was evidenced at the American Gas Association Convention at Atlantic City, where three complete refrigerators and an exposed unit were presented for the inspection of the gas industry.

Platen-Munters, independent of Geppert had like him the idea to have in the entire system, by the introduction of a second gas, everywhere the same uniform total pressures and to effect the pressure difference required for the vaporization of the refrigerating medium. Contrary to Geppert, however, they carried out this idea in a manner which at once resulted in a practical solution. They recognized what has remained concealed to Geppert that in such a system into which is introduced a pressure compensating gas there occurs within the system inner fores, i. e., physical actions which can be utilized in order to effect the circulation required for such a system. Furthermore, they recognized that this peculiar action can be

still considerably improved upon if the pressure compensating gas possesses special characteristics, for instance, as regards its specific weight differing considerably from that of the vapors of the refrigerating medium. There were ways of avoiding the pitfalls of Geppert.

First.—As regards the pump. By applying heat from a source the solution rich in ammonia, is made to boil in a tube and by the thermo-syhon action thus established, the liquid is raised from the lower level of the absorber to the high level of the generator.

Second.—Stagnation and poor circulation. Instead of using air as Geppert had done hydrogen gas was used. Absorber and evaporator are placed at about the same level or the latter somewhat higher than the former. When the ammonia vapor has been absorbed in the absorber, pure hydrogen flows through the upper pipe into the evaporator, where it mixes with the vapors from the evaporating liquid ammonia. The mixture of ammonia vapor and hydrogen being specifically lighter the greater its percentage of hydrogen, it follows that the column of gas in the evaporator will be heavier than that in the absorber. An automatic circulation of gas consequently takes place, giving an upward flow in the absorber and a downward flow in the evaporator. If instead of hydrogen, the inert gas had been nitrogen the flow would have been reversed.

The apparatus comprises the generator, condenser, evaporator, absorber, heat exchanger, thermo-syphon, which are interconnected by pipes. In all portions of the completely and tightly closed apparatus exists the same total pressure. The boiler is to a large extent filled with aqua ammonia (so called rich solution) only the upper vapor space of the boiler is free from liquid.

Into the bottom of the generator is inserted an electric heating element, connected to a source of electrical energy. From the upper free space of the generator leads a pipe to the condenser and said pipe continues on into the top of the evaporator. The latter is filled with hydrogen gas. At the bottom as well as at the top there is a connecting pipe to the absorber. The absorber is surrounded by a jacket through which circulates cooling water, which then passes to the condenser. From

the bottom of the absorber a pipe runs to and coils around the heating element. In addition there is a pipe connecting the bottom of the generator with the top of the absorber. This pipe where it is horizontal surrounds the pipe which passes from the absorber to the upper space of the generator.

The apparatus is operated as follows: Current supplied to the heating element heats the rich solution in the generator. The ammonia gas expelled from the rich solution fills the upper free space of the generator and flows through the pipe into the water cooled condenser. Because of the cooling the hot ammonia gases are condensed to pure ammonia liquid. This liquid flows to the evaporator. There in the presence of hydrogen the liquid ammonia evaporates. Through the evaporation heat is withdrawn from the brine tank surrounding the evaporator and consequently cold is produced. The ammonia gases in the evaporator diffuse into the hydrogen, and the mixture, sinks downward, because as compared to the gas mixture in the absorber it is heavy. In its downward movement it passes on to the absorber. In this vessel the gas mixture meets with the water (poor solution) coming from the generator. The liquid level in the generator is higher than the "poor solution" pipe to the absorber; there is therefore, a continual flow of poor liquid into the absorber. In the absorber the poor solution absorbs from the gas mixture the ammonia gas and collects at the bottom of the absorber as "strong or rich liquid," while the lighter hydrogen free from ammonia ascends and through the pipe connecting the absorber with the evaporator, again enters the top of the evaporator.

The rich solution is conveyed through the coils of the pipe around the lower end of the heating element and is thereby preheated so that the ammonia gas bubbles around the pipe. These bubbles carry along globules of liquid, which thereby reach the upper portion of the generator, from which we began the cycle of operation.

Outside the cycle of the ammonia which takes place in all four vessels (generator, condenser, evaporator and absorber) there occurs in the apparatus still two other cycles. On the one hand the circulation of the water, or poor solution from the

bottom of the generator, to the top of the absorber down to the bottom of that vessel as strong solution, then to the top of generator, through the thermosyphon pipe. On the other hand, the circulation of the hydrogen gas from the bottom of the evaporator to bottom of absorber, and from top of absorber to top of evaporator.

The above description covers the machine as originally designed. Rarely, has an invention required less time to perfect. On August 18, 1922, the first patent was deposited in Sweden and in 1925 a great number of refrigerating machines were in commercial service.

The Electrolux Servel Corporation has by exhaustive tests and experiments developed a machine somewhat different than the original Swedish design. These changes have practically doubled the "ice melting capacity of the machine" and have greatly increased its efficiency. They have in addition perfected the machine for gas heat instead of electric heat and have reduced the quantity of cooling water needed to properly operate the unit. In order to do this several changes had to be made to the apparatus.

1. Inner flue placed in generator to permit the use of a gas flame for heat.
2. Rectifier—to catch water that may be carried over with ammonia gas.
3. New type condenser—simplified construction.
4. Gas heat exchanger—placed between rectifier and the absorber and the evaporator, where the cold ammonia hydrogen mixture coming from the evaporator is warmed by the hot ammonia coming from the rectifier and the hot hydrogen from the absorber.
5. The liquid heat exchanger. The two pipes located between the absorber and the generator the one being placed inside the other, act as a heat exchanger on the counter flow principal, by means of this the hot, weak liquid, which flows from the bottom of the generator into the absorber, is pre-cooled by the comparatively cool strong liquid that flows from the absorber to the thermo-syphon. This solution is at the same time pre-heated before entering the generator.

The unit before being charged with ammonia, distilled water and hydrogen is given a careful air and hydraulic test under the most rigid factory supervision and after being charged is heremetically sealed by welding. The original charge does not have to be renewed, as there is no leakage.

The unit is equipped with a thermostatic safety burner which automatically shuts off the gas supplied if for any reason the supply is interrupted. One of the features of the unit is that the operation involves absolutely no danger even if the condenser water supply should be interrupted for any length of time.

Inasmuch as there are no moving parts and being rigidly constructed, no serviceing is necessary, and that is saying a lot.

The refrigerator is a steel box of approximately 6½ cubic feet of food space—finished with several coats of duco over baked white lacquer. The cooling section inside the box is of cast aluminum having five trays with a capacity of about fifty cubes. The box is insulated with three inches of high grade corkboard, thus bringing the thermal losses and operating costs down to a minimum. (From address delivered by F. E. Sellmann before the New York Section of the American Society of Refrigerating Engineers in October, 1926.)

The original ice melting capacity of the Swedish machine was about forty-five pounds per twenty-four hours while its thermal efficiency was about 18 per cent. The Swedish public were apparently content to utilize a manually controlled machine, the control simultaneously regulating both gas and water. It was found that in order to make the machine salable in this country it would have to be designed so as to operate and give sufficient refrigeration where room temperatures of 100° F. and cooling water of 90° F. were encountered. It further had to be developed so that the machine would have to give desired refrigerating effect automatically, and with controls making the unit serviceable for use with either manufactured gas, natural gas, electricity or oil. A laboratory was established in Brooklyn where exhaustive developments were made by united effort of engineers of the American and Swedish companies. During the next year these men were able to redesign the machine so as to bring about an ice melting capacity of seventy-five pounds per twenty-four hours and to raise the efficiency to 32½ per cent when operated by gas. When operated electrically the efficiency rose to 38 per cent. The machine was also capable of producing sufficient

refrigerating effect to take care of the designed refrigerator under conditions of 100° F. room temperature and 90° F. cooling water.

The maximum efficiency of the original Swedish unit was reached when an input of 730 B.t.u.'s per hour was furnished, while the maximum efficiency of the machine developed in America was reached when 1350 B.t.u.'s were used. The capacity reached its maximum at about 1300 B.t.u.'s with the Swedish machine, but with about 1650 for the American machine. These improvements both as to capacity and efficiency were brought about by many developments including a new type of rectifier, improved Thermo-syphon, and the use of a gas heater exchanger. The figures quoted above were furnished from tests conducted by the Consolidated Gas Company of New York.

As the efficiency and capacity increased with the increase in B.t.u.'s furnished the unit, it was therefore necessary to control the heat input so as to get a predetermined refrigerating effect. Using gas of 540 B.t.u. per cubic foot heating value the minimum gas required to assure satisfactory pumping through the Thermo-syphon was 1½ cubic feet per hour and this flame had to be increased to a maximum of three cubic feet per hour when maximum refrigeration was desired. This meant therefore a development of a burner that would burn satisfactorily between the ranges of 1½ cubic feet and three cubic feet per hour and that the burner in addition must be of the safety type so that, if for any reason the gas flame were extinguished that the gas supply to the burner would be automatically shut off. The first burner developed possessed these characteristics but was designed for a gas pressure of about 2½ inches of water and 540 B.t.u. gas. With the sending of refrigerating units into districts where gas pressures and B.t.u. values vary considerably it was necessary to develop burners suitable for both water coke-oven and natural gases and to test and approve gas pressure regulators.

As the minimum gas required at any time was 1½ cubic feet per hour the gas thermostat was therefore designed so as to always allow that quantity of gas to pass through it, but when the thermostat acted on the gas supply it augmented

gradually the flow until three cubic feet capacity was reached. The thermostat is of simple construction easily set and adjusted. It consists of a six inch bulb located within the food chamber. The operating mechanism of the thermostat is located in the machine compartment and is inter-connected by capillary tubing. The bulb is partly filled with a liquid which when expanded into a gas, actuates by pressure through the tube a diaphragm located in the body of the thermostat.

With operating the machine electrically, similar conditions must of course be taken care of so that the machine will continually pump. With this in mind a double heating element was developed which furnished a minimum wattage to keep up pumping but increased the wattage to take care of maximum load. From the consumption curve of the cooling water needed it will be noticed that after a certain amount of water had been used further increase in water consumption becomes unnecessary and wasteful. This therefore clearly indicated that no desirable control could be developed for controlling water simultaneously with the gas and that any water control developed would have to be designed using as a controlling factor a predetermined cooling water outlet temperature. Such a device was developed and with the outlet water temperature maintained at 90° F. the water consumption was practically halved as compared to that which was used prior to the development of this water control. The machine is now operating satisfactorily with about three gallons of water per hour with water inlet temperature of 70° F. The machine will operate and produce ample refrigerating effect with cooling water up to 90° F. With temperatures above this, the water would flow through unrestricted parts in the valve and the valve become unnecessary, but where cooling water is encountered below 90° F. the saving in water is very material. Those familiar with early tests must realize the material saving made in the water consumption and that the objections raised to water cooling, both as to waste of water and costs has been overcome.

The machine unit comprising the generator, evaporator, absorber, rectifier and gas heat exchanger is made of heavy steel tubing inter-connected by steel pipes, all joints being

oxy-acetyline welded. This produces a completely sealed unit from which there is no danger of leakage. The units are designed to withstand a pressure of 3100 pounds per square inch although only about 200 pounds charging pressure is used, and a certain proportion of the run of units are tested to this pressure at the factory. Each unit, however, is subjected to a high pressure test in order to detect any possible imperfections in welding.

From time to time one hears many stories reflecting on the safety of gas-fired absorption machines. This all emanated from experiences of ten to fifteen years ago when a few gas-fired intermittent absorption machines were being marketed, most of them of large capacity for commercial use. A few serious accidents practically eliminated further progress in this type of machine, and produced adverse legislation. The cause of this trouble was largely due to a lack of understanding as to the necessary safety devices that are required on a large intermittent machine. In other words, a machine of this kind requires automatic mechanism to shut off the fuel at the end of the boiling period, to apply cooling water at the right time both for condensing and absorbing purposes, and a pressure limiting device in the event that the gas fuel or condensing water did not function properly. The fact is these variously needed devices had not been properly perfected before the machines were marketed. Since that time there has been considerable progress made in small intermittent machines, so that in some cases for certain types of work the objections of the past have as a rule been overcome.

The Electrolux-Servel unit incorporates features which make safety devices not only unnecessary but undesirable. The fuel burns continuously, and continued operation of the maximum burner adjustment would merely produce an extremely cold box. In practice this is prevented by making the gas consumption depend upon box temperature. If, for any reason, the cooling water were to fail nothing would happen other than that the refrigeration would cease. The reason that no safety device is required to meet this condition is due to the design of the machine, which provides so much radiating surface, in proportion to the heating surface,

that all parts, with the exception of the generator will throw off the heat as fast as it is applied, through all the surfaces as represented by the evaporator, heat exchanger, absorber, condenser and rectifier, and a state of equilibrium will be reached when these surfaces will throw off the heat at the same rate as heat is applied to the generator. These two features absolutely eliminate the need of any safety devices whatsoever for the purpose of safe operation.

For an entirely different reason, however, a fusible plug is installed on the absorber end of the gas heat exchanger. This was made at the suggestion of the New York Fire Department, as well as the National Board of Fire Underwriters, and is to provide for that emergency which would be brought about by intense exterior heat being applied to all parts of the machine as would be the case if a fire occurred in the room in which the refrigerator were installed. To meet this emergency the fusible plug set to melt at 200° F. would simply relieve the refrigerator charge. This is a precaution which would be just as important if the machine were simply filled with either water or air, as the unlimited heat supply would simply produce an internal pressure which would eventually rupture the machine. These facts are borne out by the approval of the machine by the National Board of Fire Underwriters' Laboratory in Chicago, and by recent changes in the proposed code for the city of New York.

This machine has long since passed its experimental stage. When first brought out into production 250 sample boxes were sold to the various gas and public utility companies for the purpose of having them conduct tests and determine if the machine and box were what they desired and what was claimed it would do. Apparently the machine and boxes designed met with instant approval as is evidenced by the large order placed for this machine. The machine lends itself to and is particularly suitable for apartment house service especially in large and congested cities where the fact that it is absolutely noiseless, safe and serviceless has been deciding factors in its reception.

The unit may also be used in specially built boxes of varying sizes, built to fit into particular niches as seems to be the growing demand in new apartment house construction. There

is also a combination of a gas stove and refrigerator where a gas stove is mounted on a refrigerator box the same gas service line serving both. There are operating right now in the Eastern districts embracing environment of Metropolitan district of New York approximately one thousand machines. The servicing of these machines, in case it were necessary, would, of course, be done by the gas company, and from the information received they advise that so far they have not experienced any servicing whatsoever.

One question has undoubtedly occurred to a good many of you. "What effect has the gas flame with its products of combustion on the interior of the gas flue which passes through the generator?" In view of the fact that the gas flame is not extinguished but ranges in degrees from 1½ cubic feet per hour to 3 cubic feet per hour results in the gas flue always being kept at a temperature higher than the dew point.

Numerous people have asked the question, "What corrosion will take place within the unit?" Before the unit is charged with ammonia, distilled water and hydrogen, a high vacuum is pumped. Practically all oxygen is therefore removed. The machine, of course, has not been in service more than a few years so we can go back no further—but machines that have operated for this length of time in Sweden have been cut open and no trace of corrosion has been found.

The dissociation of ammonia into nitrogen and hydrogen is an old story in absorption systems where numerous joints and connections are used. In the Platen-Munters Refrigerating unit—there are no joints, no possibilities of air leakages. Then, too, if there should be a tendency to break down the ammonia into nitrogen and hydrogen—it must be remembered that the unit has already a heavy charge of hydrogen and this would tend to repel the dissociation.

Another question that has apparently been causing some comment by refrigerating engineers has been the possibility of leakage of hydrogen through the steel. As long ago as about 1860 it became known that hydrogen is absorbed by certain metals and can be diffused through them. This matter has since this time been subject to a large number of investigations which have mostly centered on the diffusion of hydro-

gen through iron and steel, as this for several reasons is of considerable technical interest.

It was known from these investigations that gaseous hydrogen easily penetrates and diffuses into steel at red heat. This diffusion, however, is sharply reduced with the lowering of the temperature and has seldom been observed at a temperature below 300° C or 572° F., wherefore some investigators have assumed a discontinuity of the diffusion at this temperature, or a "hydrogen point" of the steel. On the other hand it was shown that hydrogen which had been introduced into the steel electrolytically would diffuse through the metal at even room temperature.

As the Platen-Munters refrigerating unit contains hydrogen at ordinary room temperature under relatively high pressure, it was desired to determine if any appreciable loss of hydrogen would occur under these conditions. Earlier investigations had indicated that the losses would be quite small, but as no figures were available regarding their actual magnitude, tests were arranged and conducted by Professors Borelius and Lindblom at the Royal Technical School at Stockholm.

Applying the data obtained to the Platen-Munters refrigerating unit, we find that no danger exists of loss of hydrogen through the wall of the apparatus. For instance, if we take a 60 cal. refrigerator which contains 1.5 gr. hydrogen and which will still operate if 0.3 gr. of this hydrogen were lost, we would find that it would take one hundred eighty years before sufficient hydrogen escaped making the apparatus inoperative. This certainly gives a wide margin of life.

Thousands of people have examined this machine, among them a large number of engineers; in fact, generally speaking, the more technical a person is, the greater appeal has been made by the machine. The fact that the machine is noiseless, free from moving parts, compact, economical in operation and has apparently unlimited life, cannot but make us reflect on its effect on domestic refrigeration.

When we consider that this machine is the first of its kind, and if we compare it with other developments in the past, we can readily visualize that the continuous absorption machine will also follow in the path of progress.

Does this not make us wonder if the absorption principle will not soon be a vital factor in domestic refrigeration? (From an address delivered by F. E. Sellmann at the American Society of Refrigerating Engineers meeting in May, 1927.)

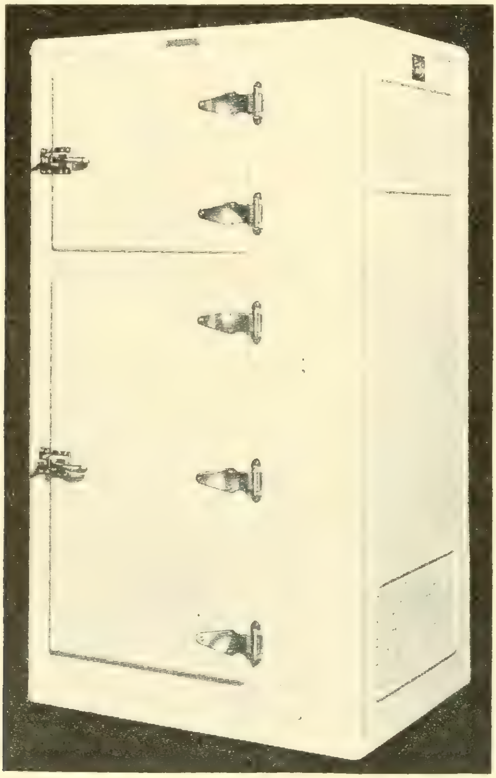


FIG. 166.—ELECTROLUX SERVEL REFRIGERATOR CABINET.

Fig. 166 shows the refrigerator cabinet. The exterior is made of lead coated steel finished with white duco. Fig. 167 shows the cooling unit and food compartment space. The food capacity is 6½ cubic feet. The box is insulated with three inches of corkboard. The lining is of porcelain and the cooling section is of cast aluminum having five trays with a capacity of fifty cubes of ice.

Fig. 168 shows the machine mounted on the side of the cabinet. The water control valve is mounted on an outlet water line. The purpose of the water control is to throttle

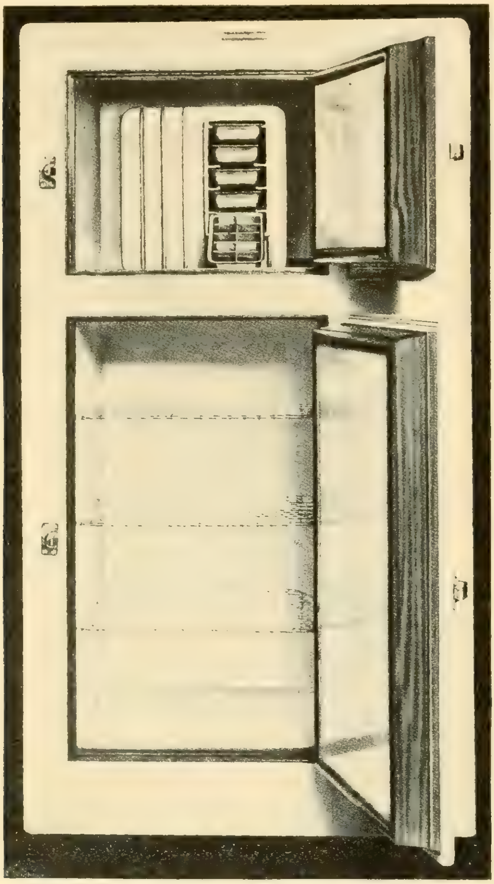


FIG. 167.—SHOWING COOLING UNIT AND FOOD COMPARTMENT SPACE

the water used in the condenser so as to maintain a constant outlet temperature under all conditions of inlet temperature and pressure. The gas thermostat automatically regulates the supply of gas responsive to the temperature of the food compartment.

A safety gas burner is used so that the gas supply is automatically shut off if for any reason the gas flame is extinguished.

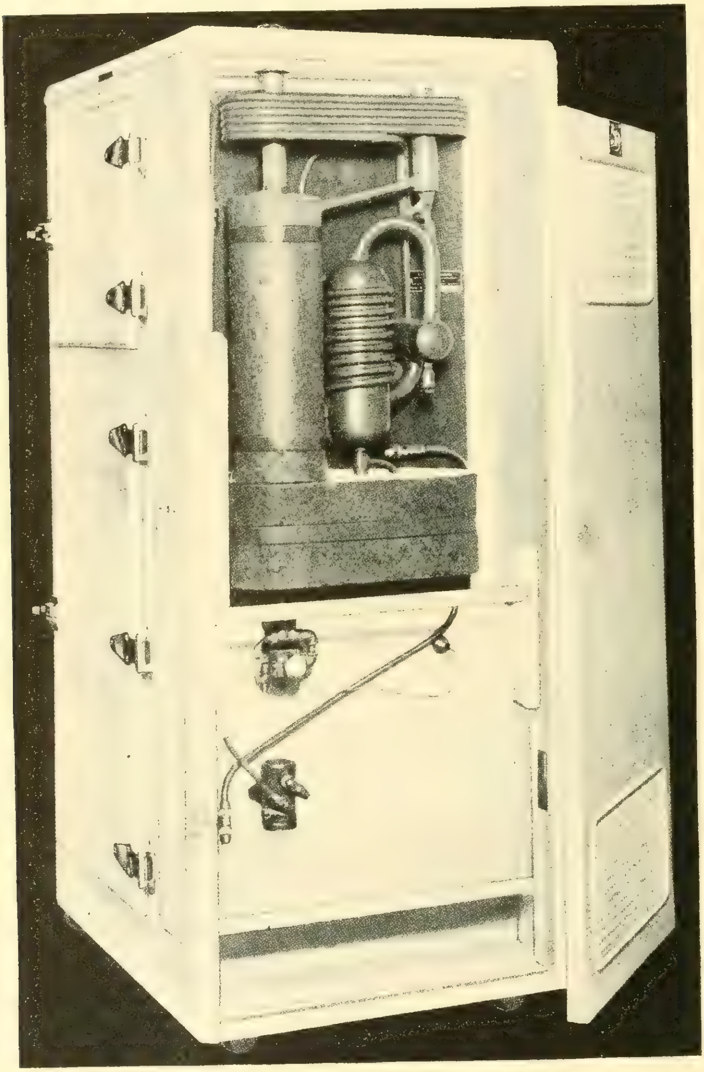


FIG. 168.—SHOWING ELECTROLUX SERVEL MACHINE MOUNTED ON SIDE OF CABINET.

Sorco Gas Absorption Refrigerator.—The new Sorco Gas Absorption Refrigerator (Figs. 169 and 170) which is manufactured by the Gas Refrigeration Corporation, with sales office at 18 East 41st Street, New York City, has a great num-

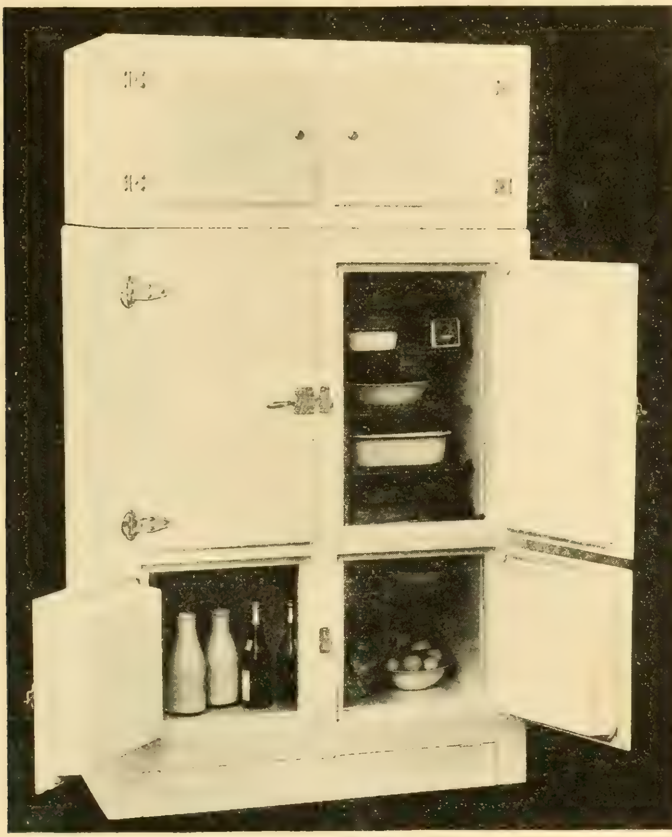


FIG. 169.—SORCO GAS ABSORPTION REFRIGERATOR.

ber of new features not shown in their old construction described heretofore.

The boiler absorber contains a solution of ammonia and water. As cold water attracts and absorbs or dissolves ammonia, the rate at which it does so and the amount it absorbs depend on the temperature of the absorbent. On the other

hand, hot water repels ammonia in the form of a gas. Hence during the heating period, ammonia is liberated from the boiler, liquefied in the condenser and fills the evaporator. During the refrigerating or absorbing period of the cycle which

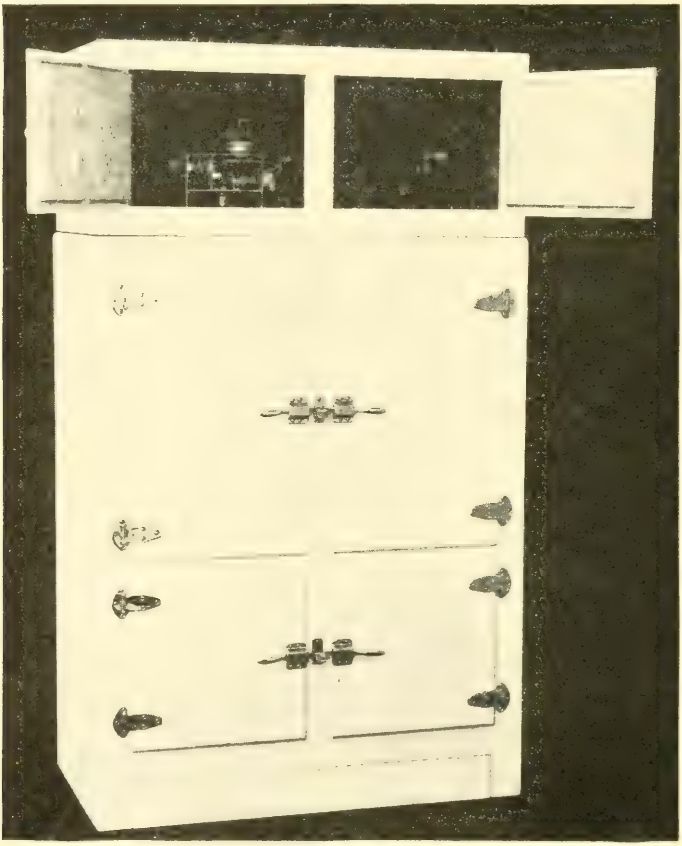


FIG. 176. SORCO GAS ABSORPTION UNIT INSTALLED IN REFRIGERATOR.

may last from eight (8) to seventeen (17) hours, according to the required amount of cold, the liquid anhydrous ammonia gasifies from the evaporator and returns to the boiler absorber where it is reabsorbed by the weak liquor. The heat absorbed by the evaporating ammonia as well as the heat of association generated by the absorption of the ammonia gas in the weak

liquor in the boiler absorber are carried off by the cooling water.

The patented construction and design of the Sorco Boiler Absorber are extremely simple as it contains no moving parts such as valves of any kind, floats, by-passes, packing or stuffing boxes or anything that can possibly get out of order. In all intermittent absorption machines ammonia gas must be expelled from the top of the liquid level and re-absorbed underneath the surface of the liquid. We accomplish this by an application of gas heat to the boiler as well as the absorber, at which time an over pressure is created in the absorber during the boiling period which keeps the aqua ammonia floating in the boiler compartment until a predetermined maximum is reached in the boiler when the required amount of ammonia gas is expelled to the condenser.

Shortly after the beginning of the absorption period the remaining weak liquor in the boiler flows back to the absorber to a lower pressure created by the cooling water flow which is diverted through the absorber at the same time the heat is turned off.

A number of novel patented features are embodied in the Evaporator construction. As shown in the diagram attached, there is no moveable part in the ammonia system which is hermetically sealed in steel vessels and seamless steel tubing welded to the tanks. As the same pressure exists during the boiling period in all parts of the evaporator a great part of the ammonia would condense in the cold evaporator which would warm it up so that the food compartments and the ice in the evaporator would melt. Condensation in the evaporator is reduced to a minimum in the construction shown. The first entering fluid ammonia fills above the coils. Condensation cannot take place in the coils as they never become empty. Condensation must then first take place in the evaporator in the reduced surface area inside the main upper vessel which quickly increases the temperature of this vessel at the beginning of the heating period. But as soon as the temperature of this main vessel reaches a certain temperature slightly above the cooling water temperature, condensation stops there automatically. This is due to the fact that only a small part of

the latent heat can escape through the air insulation between the main vessel and the housing of the evaporator. Condensation thereafter takes place only in the condenser. The evaporator housing remains unaffected by this heat which cannot circulate. The ice evaporator is able to make six (6) pounds of ice in form of 72 ice cubes, within the short time of two to three hours.

There is always a small amount of moisture in the distilled ammonia when it enters the evaporator during the heating period. This moisture not only has the tendency to increase the boiling point of the ammonia in the evaporator, thereby preventing the evaporator from reaching its minimum possible temperature, but it also would gradually accumulate in the evaporator because it does not evaporate back in the boiler absorber with the evaporating ammonia. The amount of moisture generally increases with increasing cooling water temperature and has to be removed automatically. The Sorco evaporator is equipped with a marvelously operating patented return suction tube cup which has no moveable part and is based on two functions. First, a continuously separating operation, and, second, a removing operation. The first one is performed by the ice tray supporting coils in combination with the vertical tube during the whole absorption period. The lower ends of these coils are over orifices in communication with the vertical tube, so that liquid circulation between the vertical tube and the two coils is avoided. At the start of the boiling period the remaining aqueous solution in the vertical tube and in the lower part of the coils is forced through an orifice into the sump at the bottom of the evaporator. Due to the drop in pressure shortly after the end of the boiling period a small predetermined amount of liquid in the tube cup is drawn back into the absorber. This takes place shortly after the end of each boiling period with an astonishing regularity and without returning an appreciable amount of ammonia.

The Sorco is now as formerly 100 per cent automatically operated. The attractive feature, however, is that electricity is no longer required to operate the control of the gas heated unit. The movement of the few parts in the patented control

is so simple and slight, that noise and wear are reduced to practically nil. The two thermostatic power elements, one in the boiler and one in the evaporator, control the water flow by a snap action in a simple and unique manner. The starting and stopping of the boiling period as well as three different water flows are accomplished: First, the water flow during the boiling period; second, a strong flow during the first part of the absorption period through the absorber to cool the machine down quickly, and third, a minimum amount of water flows during the most of the absorption period to extract the heats of evaporation and association.

The advantages of this non-electric control are manifold. First, it regulates the length of the cycle automatically according to the required amount of cold. Second, it is completely foolproof—if for example the power element in the evaporator should not operate due to an overload in the evaporator, the control of the machine would automatically be operated by the thermostat in the boiler. The length of the absorption period would be determined by the rate of radiation from the boiler. This condition would last as long as there is an overload in the evaporator and thereafter the evaporator thermostat would automatically start its normal operation again. Third, it is selfstarting, that is, it does not matter during which operating condition the machine was shut off as it shifts automatically to the proper starting position. Fourth, the elimination of the necessity for any electric connections in the machine, or the elimination of the possible failure of the electric current. Fifth, the elimination of the possible failure of the many intricate electrical parts such as wiring, contacts, switches, pilot wires, etc., all of which also require an electrical knowledge in the servicing.

There is a safety pilot light which automatically lights the gas whenever it is turned on. Unburned gas cannot escape, due to the automatic gas shut-off of the safety pilot; if for instance, the pilot light should go out. The gas burner cannot be lighted unless cooling water flows through the system. As long as the cooling water flows through the system it is impossible to attain abnormal or dangerous pressures in the system, and in order to comply with the Safety Code there

is a rupture device which would exhaust the refrigerant with the cooling water in closed pipes at a safe pressure below the bursting pressure of the weakest part of the system, which bursting pressure is more than twelve times the maximum normal working pressure. The normal working pressure during the refrigeration period range from 10 to 35 pounds gauge. The maximum normal working pressures during the heating periods are from 125 to 175 pounds per square inch, all of which vary according to room and cooling water temperatures.

The machine can be manufactured in all sizes. One size is on the market which has an ice making capacity of about 23 pounds per cycle. The maximum capacity is therefore about 92 pounds in 4 cycles per 24 hours.

The Sorco machine automatically defrosts the evaporator each cycle. The box temperature increases 5 to 6 degrees Fahrenheit during the boiling period.

The Sorco needs little servicing as it contains no movable parts beside the control and every machine, even when it is continuously operating, must have a control unless it is not fully automatic.

The average operating cost of the Sorco refrigerator is 11 cents per day, on one dollar gas and water at one dollar per thousand cubic feet. The third of this cost is for water and two-thirds for gas.

The Sorco Model E consumes from 40 to 80 cubic feet of gas per day according to conditions and the required refrigerating effect. The average water consumption is under 200 gallons per day.

CHAPTER IX

TYPES AND CONSTRUCTION OF HOUSEHOLD REFRIGERATORS

Household Refrigerators.—The following pertains to the description of the general type and a detailed description of some of the leading household refrigerators on the market at present. The different makes of household refrigerators which are described have been selected promiscuously, and do not include all of the makes which are produced at present. However, the description of the following makes will convey an idea of the general types, as well as the various details of construction used in some of the leading makes at present. Special attention is given to wall construction, linings, outer case construction, construction of doors, etc.

Bohn.—In Fig. 171 is shown a typical refrigerator made by the Bohn Refrigerator Company of St. Paul, Minnesota, for electrical refrigeration.

The exterior is of white porcelain on steel. The lining also is made of porcelain. The walls and doors contain eleven insulating members, including two thicknesses of flaxlinum. The insulation is framed in with heavy members, insuring permanency of position and long life. It is so constructed as to present a complete refrigerator before the outer steel, porcelained case is installed. The porcelain steel case is added to beautify its appearance and as an added protection to the inner walls. The walls are 3½ inches thick and the doors 3¼ inches.

Doors are built on the safe door principle, with several rabbets to hold back the air leakage and in addition are furnished with cushion gaskets.

All hardware is solid brass, nickeled in the company's plant. Corners are trimmed with solid brass tubing, heavily

FIG. 171.—TYPICAL BOHN REFRIGERATOR.

nickeled. Underneath this trim are white wood mouldings, which seal the porcelain plates together—an additional moisture proofing.

The food chamber lining is one-piece heavy steel, porcelained, with full rounded corners and rolled door edges. All porcelain steel, inside and outside, has one ground coat on both sides of the sheet and then two additional coats of white, each coat fused on separately, in its own plant, in ovens carrying two thousand degrees of heat.

The cooling chamber is lined with the highest quality galvanized steel with a copper alloy base.

The drain pipe is solid brass, with a spun copper funnel top and solid brass base, all heavily nickeled. The drain trap is double—a large opening if ice should be used, and an auxiliary, removable, smaller trap within the larger trap, for defrosting drainage. Defrosting drainage should be carried away from the inside of the refrigerator and never be left in a pan inside the refrigerator because of the high content of bacteria and food decay in the melted frost. The provision shelves are meshed wire, heavily tinned.

There are proper circulation principles, inbuilt, leading the air in a complete circulating course throughout every part of the provision and cooling chambers.

Equipment includes a porcelain shield for cooling chamber door opening. Stud bolts in ceiling of cooling compartment with basket hanger, where necessary, and a sleeved hole in back; complete equipment for installation of cooling unit.

A full line of household refrigerators, with or without subbases, is manufactured.

The porcelain base may be used to house the refrigerating machine. When the machine is not placed in the base, the base can be used for the storage of water bottles, kitchen ware or canned goods.

Cavalier.—Fig. 172 shows the construction of a refrigerator made by the Tennessee Furniture Corporation, Richmond, Indiana. This view has the walls cut away to show steel frame construction. A structural frame of angle iron is used. The joints are electrically and acetylene welded.

There is an exterior case of porcelain enameled steel sheets, backed up by wall board and bolted to the steel frame. Next is a ¾-inch air space, and 1½ inches of corkboard. The interior porcelain lining is encased in an airtight envelope of

insulation. The corkboard walls are entirely covered with a special preparation. Seal Tight, which is waterproof, closes all air-cells, and prevents deterioration.

A removable plate at the back of the ice chamber is for the convenience of those who wish to install an electric refrigerating unit.

Doors are made with a heavy wood case, to which the cork insulated door pans and wood moulding are firmly fastened.

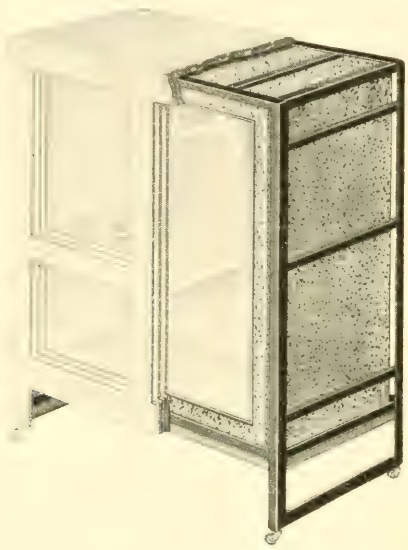


FIG. 172.—CAVALIER REFRIGERATOR, SHOWING CONSTRUCTION.

The door surface is covered with a metal case held firmly in place by flanges folded over the edge of the wood core. All doors are of the heavy, overlap type and are fitted with "Wirfs" insulating gaskets to prevent air leakage and to give cushion action at the door jamb.

Fig. 173 shows one of the white porcelain lining and exterior models. These refrigerators are so constructed that an electrical refrigerating unit may easily be installed.

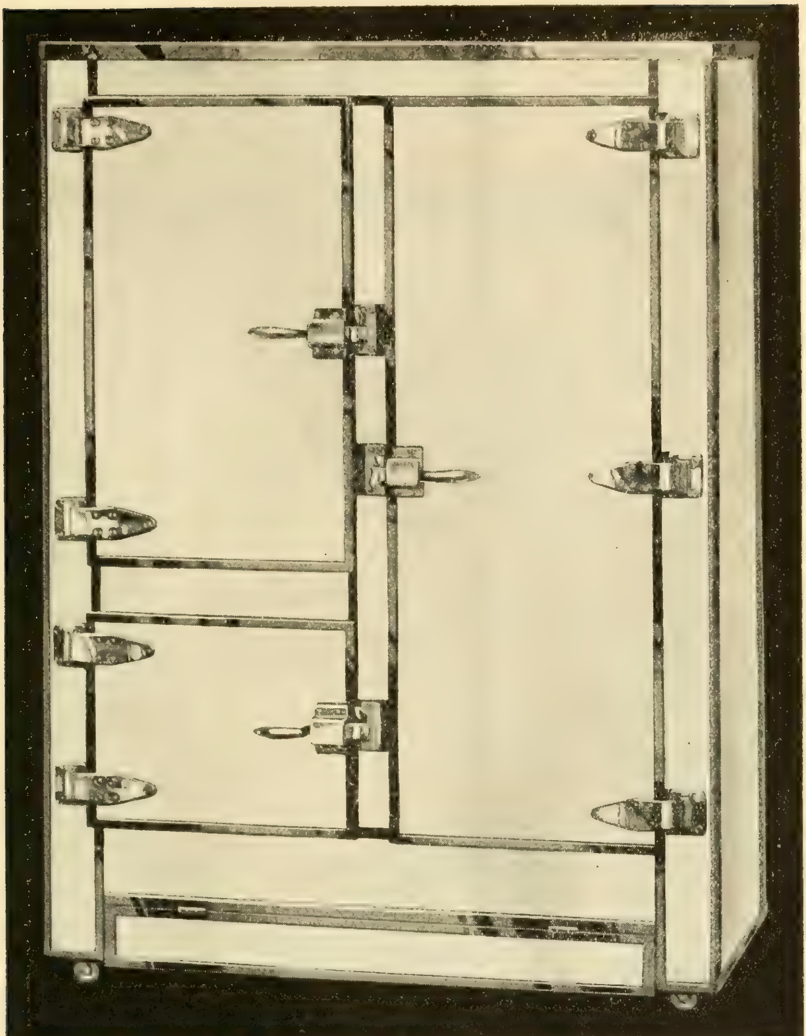


FIG. 173.—CAVALIER REFRIGERATOR, WHITE PORCELAIN EXTERIOR.

Crystal Refrigerator.—Fig. 174 shows an all-metal refrigerator made by the Crystal Refrigerator Company, Fremont, Neb.

Some new and interesting features of construction are incorporated in the design of this cabinet.

The walls both outside and inside are made of one-piece galvanized sheet metal with a hard, baked white enamel finish. Porcelain linings can also be supplied.

The walls are insulated with from 2 to 5 inches of pure

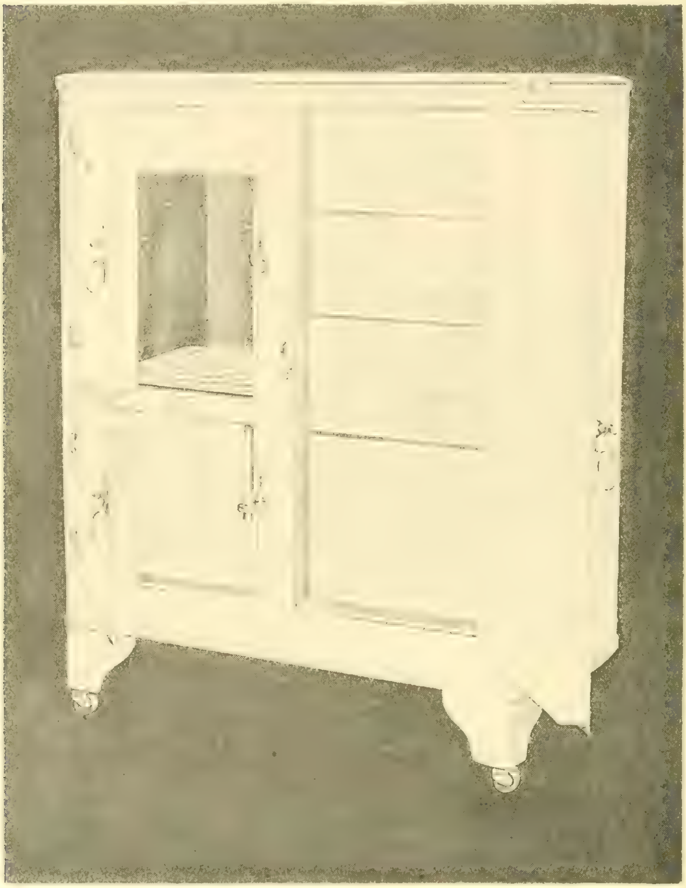


FIG. 174.—CRYSTAL REFRIGERATOR

granulated cork. A wooden frame is used to strengthen the walls and to support the door latches and hinges.

Aluminum moldings and corner pieces at the top and an aluminum band at the bottom add to the appearance and protect the enamel.

Solid glass shelves are used. The ends of the shelves are square while the ends of the cabinet are oval, thus forming a passageway for the air circulation. Part of the air goes across the shelves and the balance to the bottom of the food compartment.

The doors are constructed of metal. The ice chest, shelves, and all inside parts can be easily removed for cleaning.

The trap is aluminum and located inside the refrigerator.

FIG. 175.—CRYSTAL STEEL REFRIGERATOR

Both apartment and side icer cabinets are built in ice capacities from 50 to 250 lbs. Cubical contents range from 3.6 cu. ft. to 20.2 cu. ft.

"White-Steel" Refrigerator, Fig. 175, shows an all-steel refrigerator of the square type by the Crystal Refrigerator Company, Fremont, Neb.

The walls are constructed the same as the Crystal but are not so heavy. They are insulated with 1½ in. to 3½ in. of pure granulated cork.

Wire shelves are used.

The doors are constructed of metal. The ice chest, shelves and all inside parts can be easily removed for cleaning.

The trap is aluminum and located inside the refrigerator. Made in apartment and side icing styles in ice capacities from 50 to 150 lbs. Cubical contents range from 4.2 cu. ft. to 9.6 cu. ft.

Jewett Refrigerator.—The Jewett Refrigerator Company of Buffalo, N. Y., has been building refrigerators since 1849. Fig. 176 shows a typical Jewett side icer cabinet.

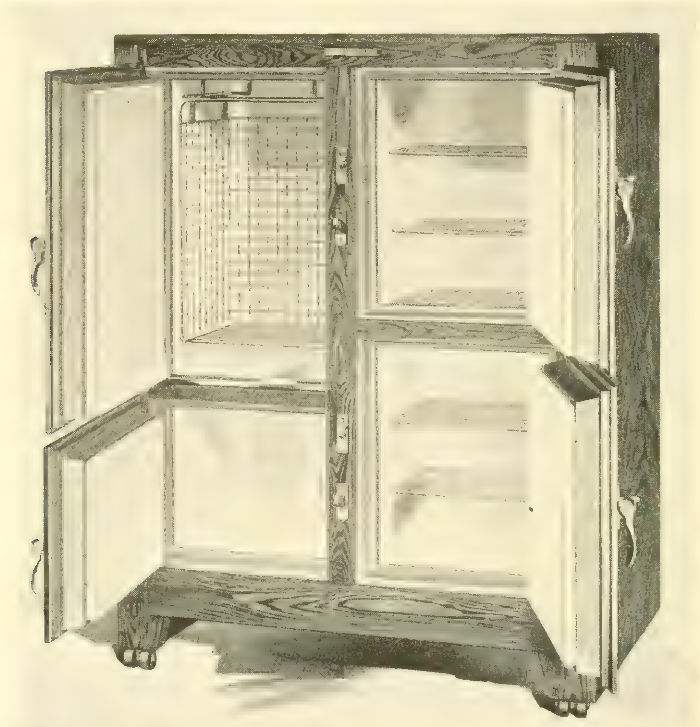


FIG. 176.—JEWETT REFRIGERATOR.

The lining is of solid porcelain 1¼ in. thick. This lining is of earthenware which is fused at 2500° F. The ice compartment is lined with the same material. A modern pottery is used to make these linings and they form an ideal interior surface for a refrigerator. This lining has some heat insulating value and has a certain heat capacity which acts as a

stabilizer of temperatures in the food compartment. The amount of ice in the refrigerator may vary consideraby without appreciable effect on the temperature of the food compartment. The doors are lined with white opal glass. The flues are formed in the porcelain linings and are of generous size insuring good circulation.

The drain, shelf supports, flues, and ice compartment floor are all cleverly molded into the lining, affording a simplicity

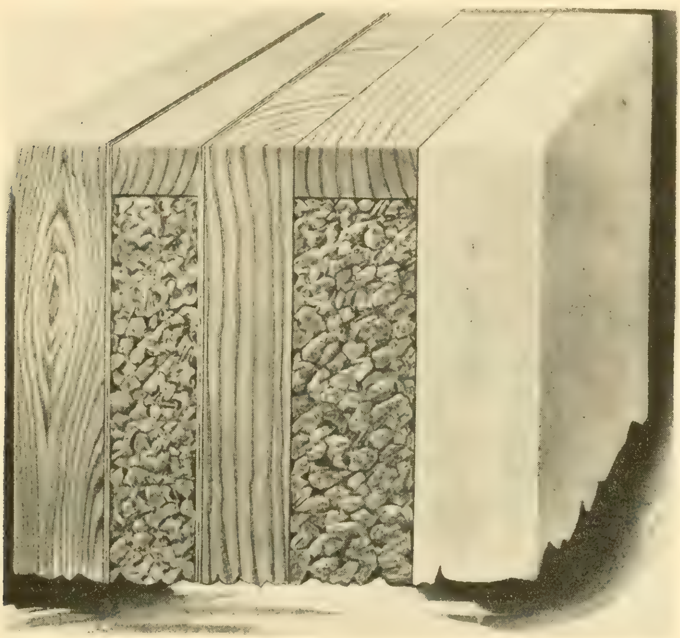


FIG. 177.—JEWETT REFRIGERATOR WALL SECTION.

of design which greatly adds to the appearance of the interior of the cabinet.

The insulation is shown in Fig. 177. The total thickness of this wall is 5⅜ in. The interior case is of solid ash, doweled and glued; next comes two layers of waterproof insulating paper, then 1 inch of pure sheet cork, two more courses of heavy waterproof insulating paper, a course of ⅞ in. tongued and grooved lumber, 1¼ in. of pure cork, one course of insulating paper and then 1¼ in. of solid porcelain lining. This

construction insures a wall of low heat conductivity, and a wall which will not be damaged by very low food compartment temperatures.

The ice is supported in a heavy mesh container, which is held by rods bolted firmly to the ceiling. This container is easily removed for cleaning.

FIG. 178.—JEWETT REFRIGERATOR.

The door construction is very rigid. The design includes a door of good appearance which will close tightly and not warp out of shape under severe humidity conditions. Cabinets are constructed with holes through the lining so as to accommodate mechanical refrigerating units.

Another line of refrigerators, Fig. 178, is made having a lining of one piece seamless steel coated with white vitreous enamel baked on at high temperature. The corners are rounded.

The insulation is 3 in. of pure sheet cork bonded to the lining with moisture-proof hydrolene. This prevents any dead air spaces between the lining and corkboard.

The exterior may be obtained in natural ash or white

FIG. 179.—SHOWING SPECIAL COMPARTMENT JEWETT REFRIGERATOR.

enamel finish. The partition around the ice compartment is easily removable. The shelves are made of heavy woven wire coated with pure block tin.

A special utility space, Fig. 179, is located directly under the ice compartment to be used for cooling bottles, storing extra ice cubes, or chilling fruit or vegetables.

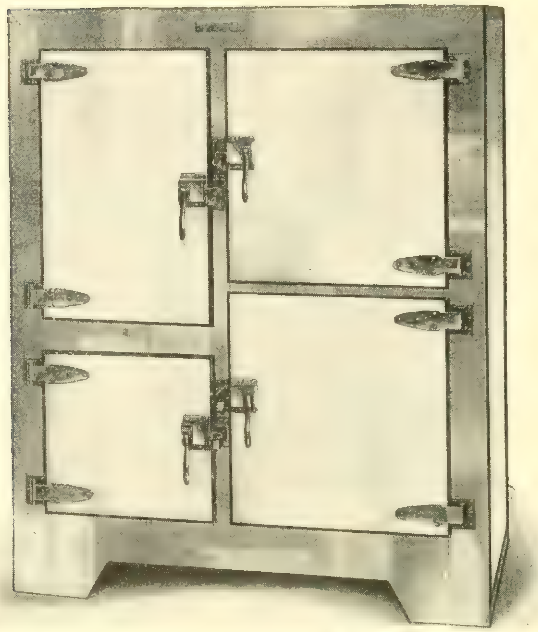


FIG. 180.—JEWETT REFRIGERATOR WITH MONEL METAL EXTERIOR.

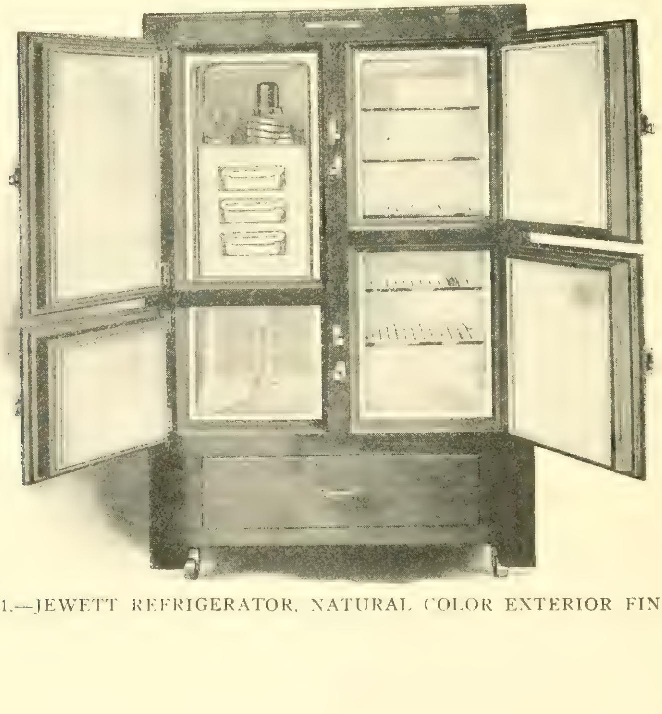


FIG. 181.—JEWETT REFRIGERATOR, NATURAL COLOR EXTERIOR FINISH.

Another line of refrigerators, Fig. 180, is made. This model has a porcelain enamel and monel metal exterior. The lining is of solid porcelain.

Two other standard exterior finishes are furnished. Natural color, brown ash, Fig. 181, with three coats of varnish, satin finish. The hardware is of solid cast brass. The other standard exterior finish is five coats of white enamel, with nickel hardware.

Cabinets are made in side and top icer types with ice capacities from 75 to 240 lbs. The Jewett Company also makes a specialty of building cabinets to order.

Leonard Refrigerator.—Fig. 182 shows a typical refrigerator as built by the Grand Rapids Refrigerator Company, Grand Rapids, Michigan.

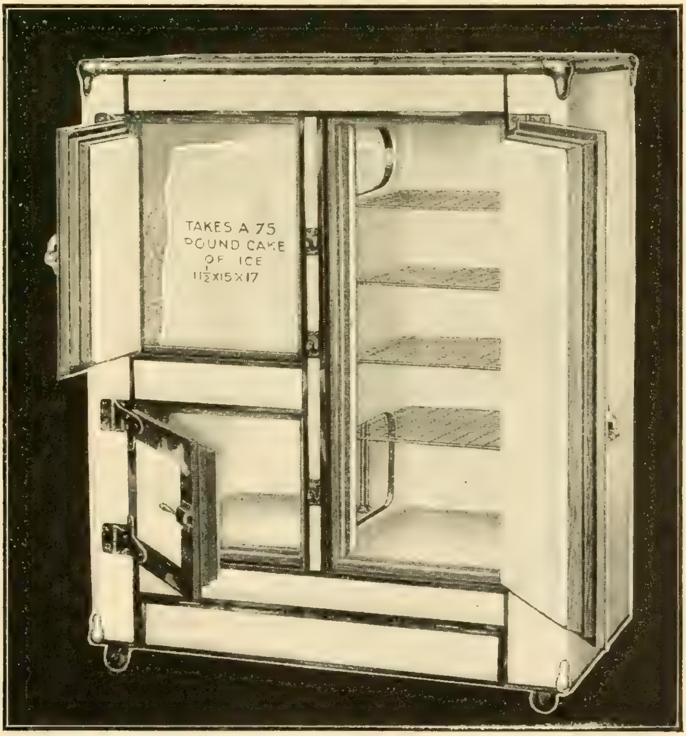


FIG. 182.—LEONARD REFRIGERATOR.

The Leonard refrigerator has been built for over 43 years and represents the latest cabinet construction for large quantity production.

The exterior case on the different models is made of porcelain on steel, white enamel on steel, 5-ply laminated wood or quarter-sawed oak.

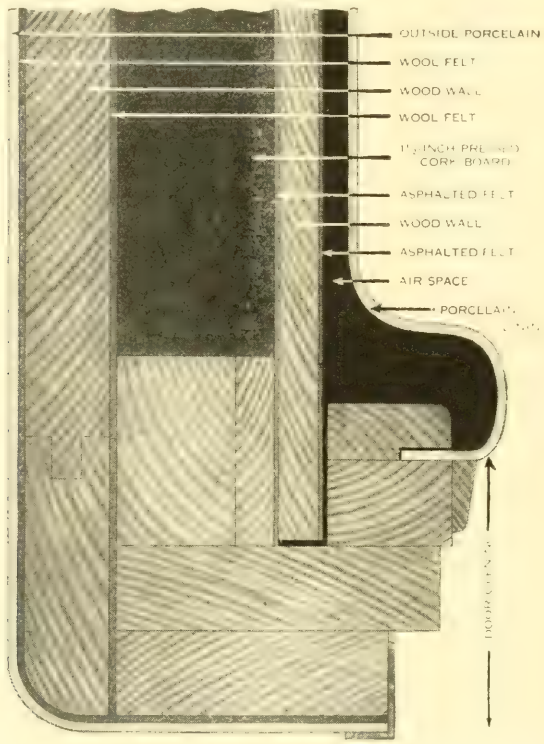


FIG. 183.—SECTION OF LEONARD REFRIGERATOR WALL.

The better grade of cabinets have corkboard insulation. A typical wall construction is shown in detail in Fig. 183.

One-piece porcelain linings are used. These linings are made of Armco ingot iron. The sheets of iron are first cut, punched, and welded, forming one piece of steel, thus producing a lining with a smooth, hard surface which eliminates cracks and sharp corners. They are next immersed in acid

to remove all grease or dirt, through other cleaning processes and then thoroughly dried. The steel linings are then dipped in a dark-blue porcelain composition which is fused on to the steel at a temperature of about 1800° F. Two coats of white

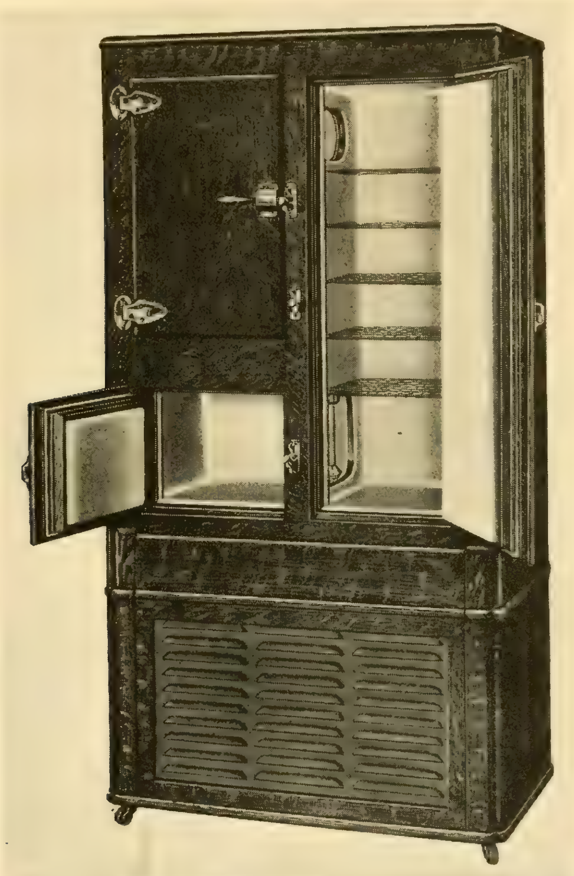


FIG. 184.—LEONARD OAK REFRIGERATOR WITH DETACHABLE BASE FOR ELECTRICAL REFRIGERATING UNIT.

porcelain are then applied and baked on in a similar way. This forms a white surface which is impervious to rust and disintegration.

The cold-air flue construction between the bottom of the ice chamber and the top of the small porcelain provision

chamber is such as to allow for a free circulation of air into and through the provision chambers, there being a circular opening in the porcelain lining.

Many different types and sizes of refrigerators are made with ice capacities from 20 to 495 pounds.

Fig. 184 shows an oak cabinet with a special detachable base for electrical refrigerating machines. In this refrigerator the necessary bolts and perforations have been inserted to make it convenient to install the cooling unit in the ice chamber.

This cabinet is made in all-porcelain, oak-porcelain, ash-porcelain and steel-klad lines. Openings are provided for ventilation.

Many other different types and sizes of refrigerators are made with ice capacities for 20 to 495 pounds.

McCray Refrigerator.—The McCray refrigerator has been built at Kendallville, Indiana, for over thirty-five years. Fig. 185 shows one of the side-icer type McCray cabinets.

The standard exterior construction is quarter-sawed oak made of 5-ply laminated wood. The top and bottom of the refrigerators are so constructed that the plywood is not exposed to the outside.

The linings are made of one-piece porcelain enamel on steel. The inside of the doors is also covered with porcelain. Some of the larger refrigerators are made with both lining and exterior case constructed of $\frac{7}{16}$-inch white opal glass. The floor is of hexagon vitreous tile laid in special cement.

The insulation consists of 2 inches of pure corkboard sealed with hydrolene cement. The wall section comprises:

1. Porcelain enamel lining.
2. Dead air space.
3. Inside wood lining.
4. Waterproof paper.
5. Two in. of corkboard sealed with hydrolene cement.
6. Waterproof paper.
7. Exterior case of 5-ply laminated wood.

Every model has studs in the ceiling of the ice compartment on which cooling units may be hung for electrical refrigeration.

A sub-base for any stock model may be supplied so that the electrical refrigerating unit may be installed under the refrigerator cabinet. This base is slatted to permit using an air-cooled refrigerating machine.

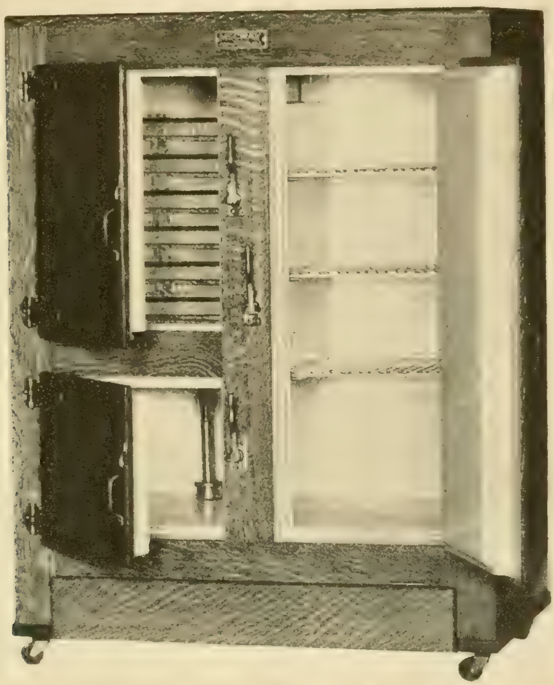


FIG. 185.—McCRAY REFRIGERATOR.

Cabinets of various types with ice capacities from 60 to 840 pounds are made.

Fig. 186 shows one of the all-metal exterior refrigerators for electrical refrigeration.

The exterior of these all-metal refrigerators is covered with automobile steel. The joints of this steel are braced together making this exterior practically one piece. A pyroxyline lacquer white finish is applied making a beautiful white exterior. This is the same finish as used by high-grade automobile body manufacturers.

The doors are flush paneled. They have a ¾-inch raise, and are provided with gaskets which make this refrigerator practically air tight. The hardware and hinges are of heavy

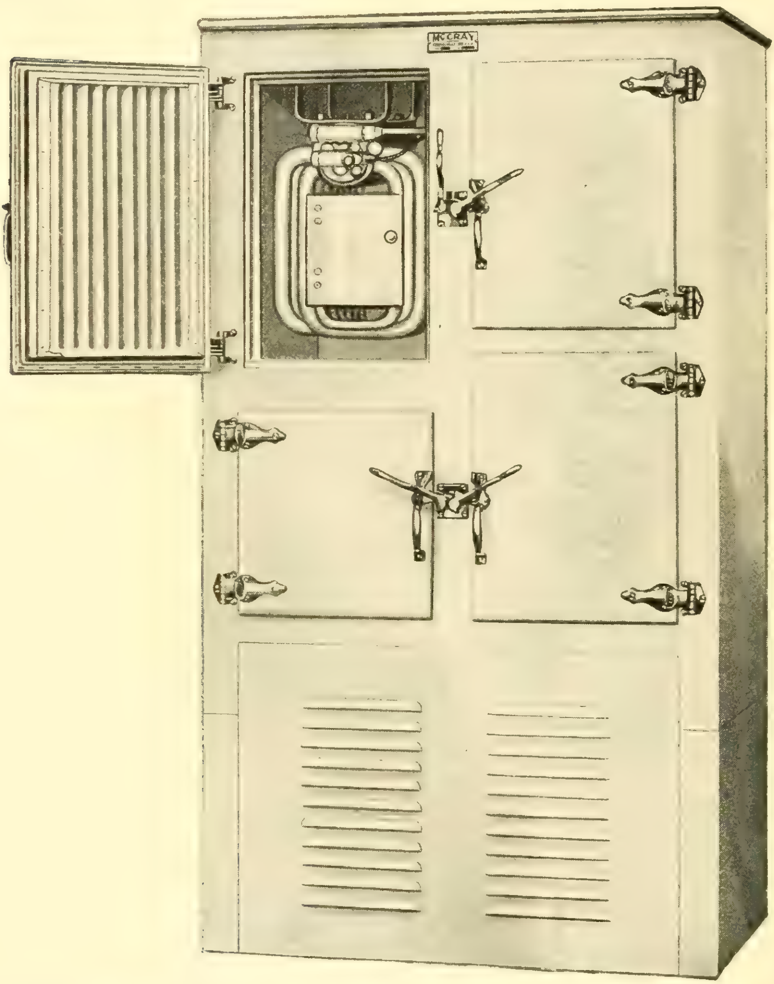


FIG. 186.—McCRAY ALL-METAL REFRIGERATOR FOR ELECTRICAL UNIT.

brass, nickel plated. Fasteners are of the self-closing type. All refrigerators are mounted on piano casters.

The interior of these all-metal exterior refrigerators is of the highest quality one-piece porcelain.

The insulation consists of 2 inches of pure corkboard, all joints being carefully sealed with hydrolene cement.

Reol Refrigerator.—The accompanying illustration shows the Reol, manufactured by the Reol Refrigerator Company of Baltimore, Md., in process of construction. The section in

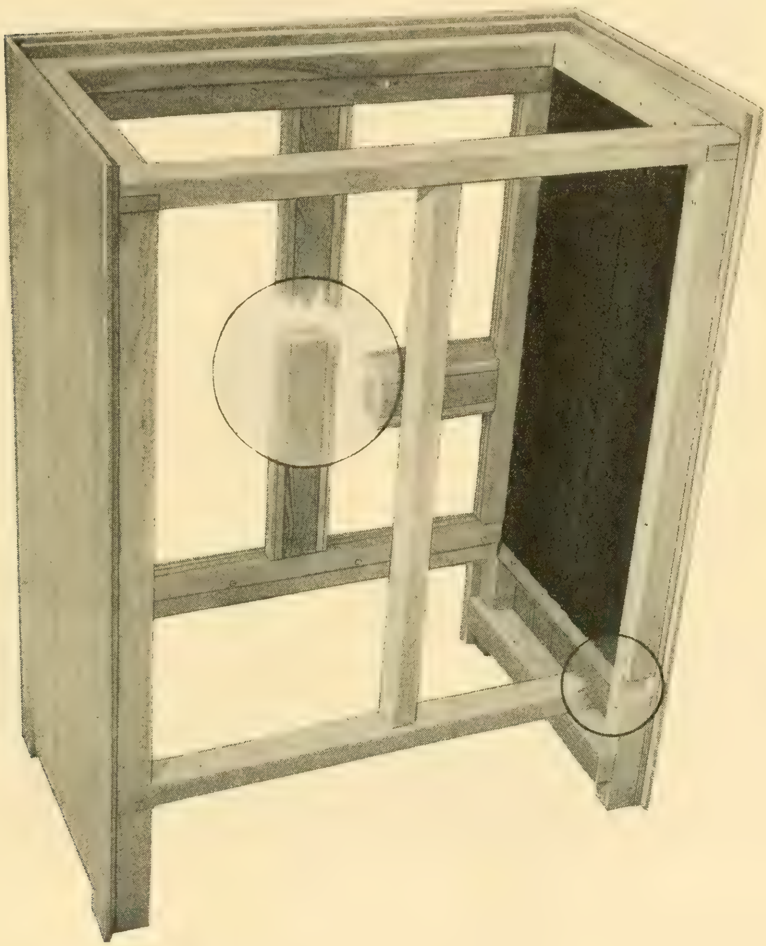


FIG. 187.—THE REOL REFRIGERATOR IN PROCESS OF CONSTRUCTION.

the small ring shows the mortised and tenoned method of joining the framework. A view of the finished refrigerator is also shown.

The framework of the Reol Refrigerator is very strong, very rigid, and very durable. It is made with ash, corner posts in one continuous piece from top to bottom. The lower ends of the corner posts extend about 8 inches below the floor

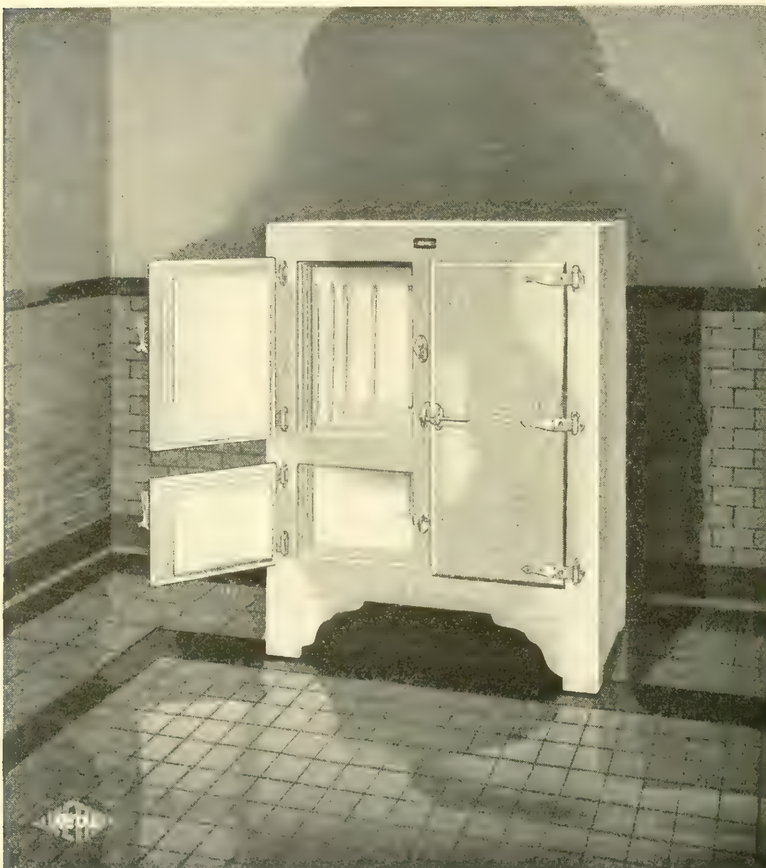


FIG. 188.—REOL REFRIGERATOR.

of the refrigerator, to form a sanitary base. The framework of the Reol is mortised and tenoned, glued, and fastened solidly together to form a rigid foundation on which to build up the completed refrigerator.

The exterior finish is of solid oak, free from knots and

imperfections, with the long boards of the side panels held together with deep tongues and grooves. The oak is filled, stained, and rubbed down coat after coat, to a hard satin smoothness, beautiful and enduring.

The insulation in the Reol Refrigerator consists of pure corkboard 2 in. thick, securely fastened to the framing. The insulation is continuous over all of the refrigerator surfaces, and is broken only by the casings of the doors on the sixth surface. The corkboard is covered with a coat of protective water-proofing on both sides, to prevent any possibility of dampness getting into it either from the outside or the inside, thus eliminating decay or odors.

The food compartment is lined with vitreous porcelain which is extremely durable and sanitary. It does not chip unless exposed to hammer blows and it will last a lifetime if given just ordinary good care. Snow white, glassy, and free from all imperfections and discolorations.

The hardware used on the Reol is of solid brass, heavy and durable. It is handsome in appearance, and will give a real lifetime of service.

The doors of the Reol contain the same insulation as the sides of the box, and in the same amount. They are made specially air tight with a series of rabbets on the door, which fit into corresponding ledges in the door casings. As a further precaution, around the uttermost ledge is a gasket of rubber and compressible cotton wick. When the door is closed, the gasket compresses and keeps the warm air out.

Rhinelander Refrigerator.—The refrigerator shown in Fig. 189 is manufactured by the Rhinelander Refrigerator Company, Rhinelander, Wisconsin.

The exterior is of white porcelain with trim strips of polished metal. Fig. 190 shows the interior of the same cabinet. Other models are made with hardwood exteriors in various finishes.

The lining is of the one-piece porcelain type. Cabinets are also made with white enamel linings. Corkboard is used to insulate the walls and doors.

Fig. 191 is one of the refrigerators designed for mechanical refrigeration units. This cabinet has a white porcelain interior lining with exterior case of steel, white lacquer finished. It is cork insulated. The equipment includes hanger bolts and pipe opening in the rear.

The different models include side and top icers, grocery and meat refrigerators of ice capacities from 50 to 575 pounds.

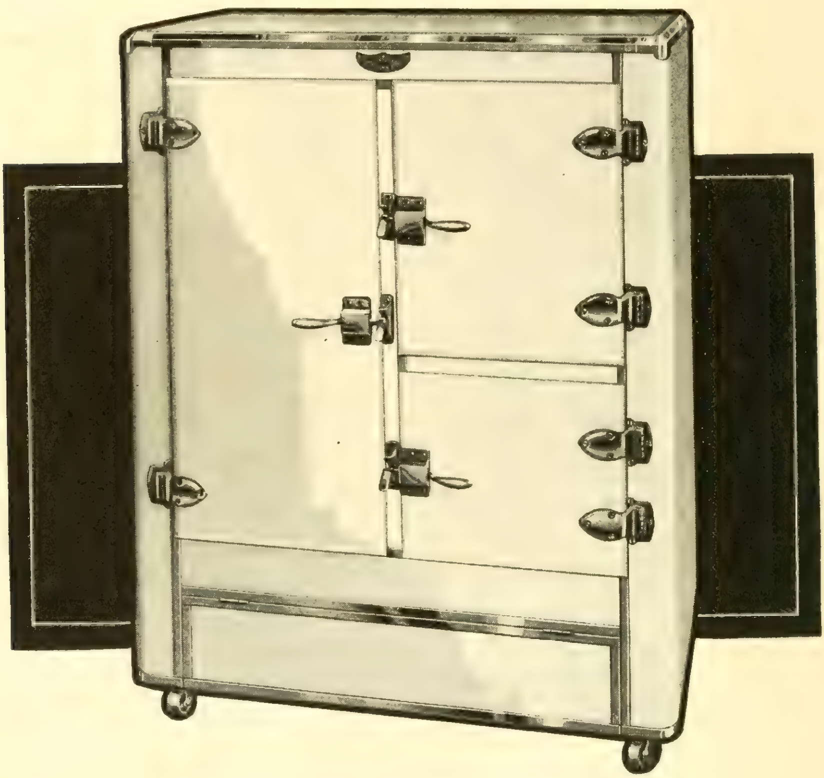


FIG. 189.—RHINELANDER REFRIGERATOR.

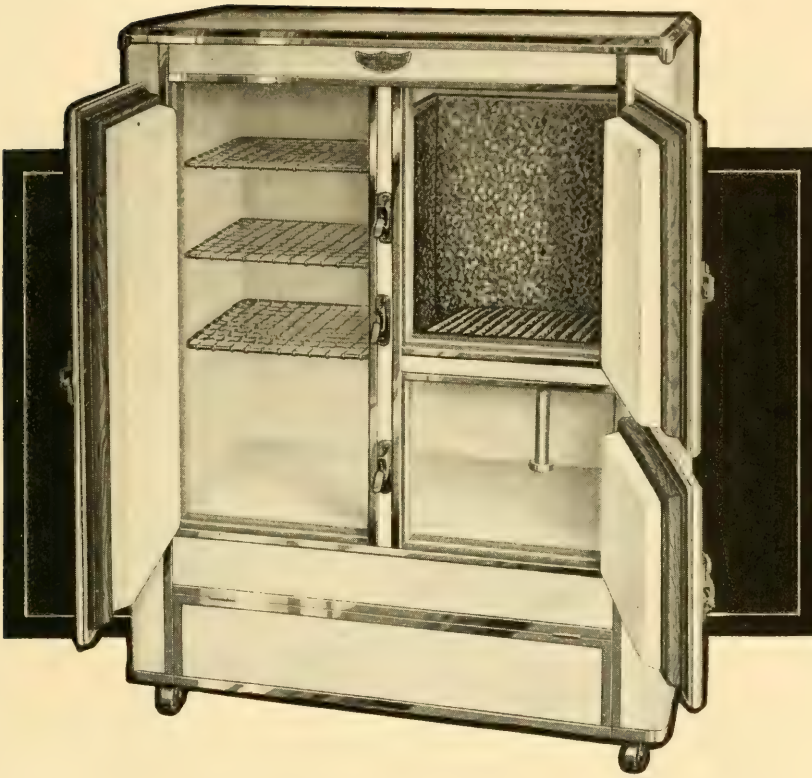


FIG. 190.—INTERIOR OF REFRIGERATOR SHOWN ON OPPOSITE PAGE.

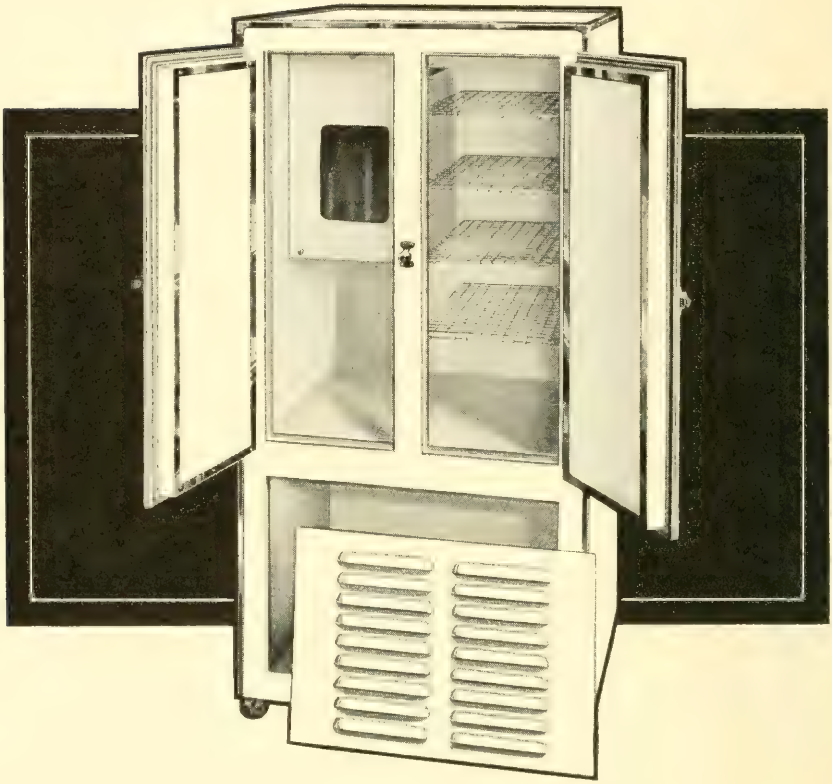


FIG. 191.—RHINELANDER REFRIGERATOR DESIGNED FOR MECHANICAL UNIT.

Seeger Refrigerator.—Fig. 192 shows a typical refrigerator made by the Seeger Refrigerator Company of Saint Paul, Minnesota, for electrical refrigeration.

The exterior and interior are of white porcelain on steel. They are equipped with porcelain defrosting pan and insu-

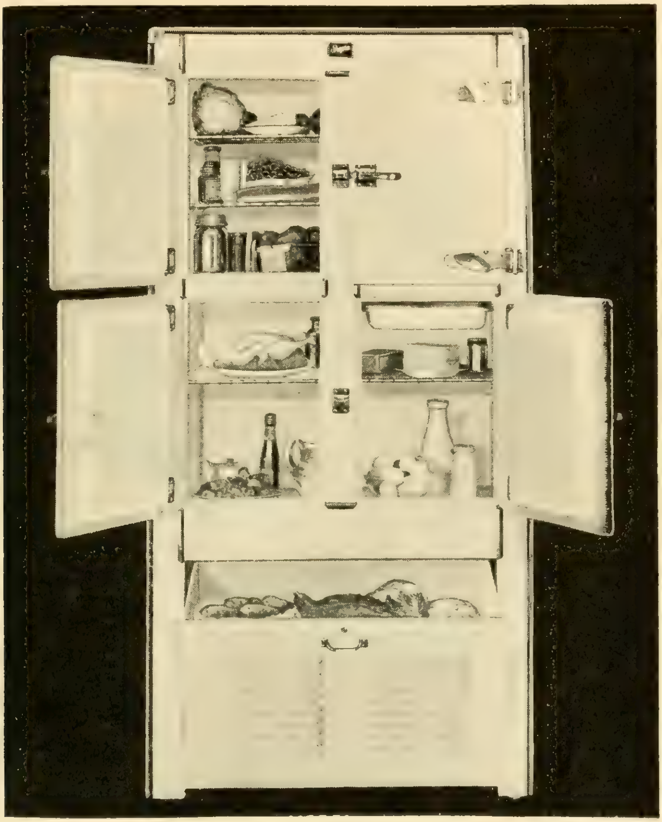


FIG. 192.—SEEGER REFRIGERATOR FOR MECHANICAL UNIT.

lated removable porcelain baffle wall. The insulating materiai used is corkboard.

Vegetable storage compartments can be supplied for all models. These are shipped as separate units complete with fittings. The vegetable storage compartment opens forward like a flour bin.

The insulation consists of waterproof insulating paper, heavy insulating board and pure sheet corkboard, hydrolene sealed, 2 inches or more in thickness.

White Frost.—Fig. 193 shows one of the White Frost refrigerators manufactured by the Home Products Corporation, Jackson, Michigan, who have been building them for twenty-five years.

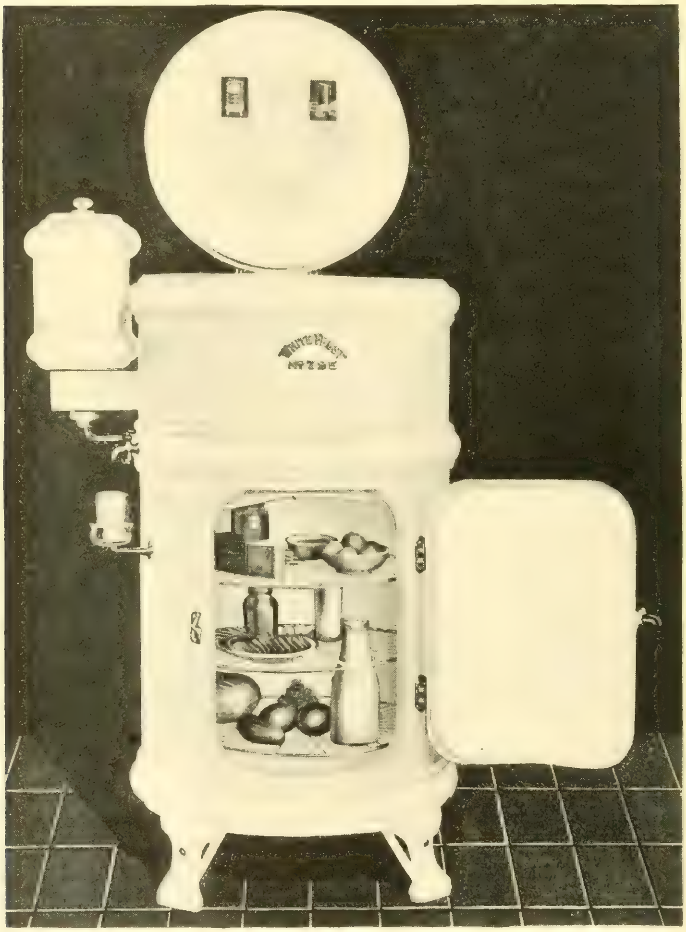


FIG. 193.—WHITE FROST REFRIGERATOR.

It is built of special rust-resisting steel and insulated with pure granulated cork in sealed air space. Cork is introduced by a special method to prevent settling. The construction is all steel. The seams and joints are sealed to be permanently air and moistureproof.

This cabinet is round with revolving food shelves, making entire shelf area accessible for storage. Shelves and ice chamber lift out for cleaning.

Construction makes it easy to maintain correct refrigeration temperatures and secure efficient circulation of pure, cold, dry air to each part of the food chamber.

The illustration shows a water-cooler type. Two sizes are available of 100 and 50-pound ice capacity. Each size is furnished with or without water-cooling system. The cabinets are finished in lacquer or white or grey enamel.

Wall Construction.—Fig. 194 shows a refrigerator wall using mineral wool insulation and a metal lining. The air

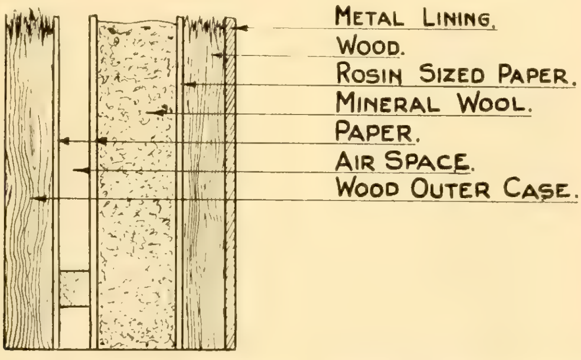


FIG. 194.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

space is placed well out from the inside lining. With usual service conditions, the air space in this position would be effective as a heat insulator.

Fig. 195 shows another wall using mineral wool and air spaces. The air spaces are placed near the inside lining. Water vapor in the dead air spaces would condense, collecting on the surface of the lining. This design is very poor from an insulation standpoint.

Fig. 196 shows a solid wall insulated with corkboard. The inside wooden frame strengthens the cabinet and prevents breaking the opal glass lining in shipment. The wooden frame

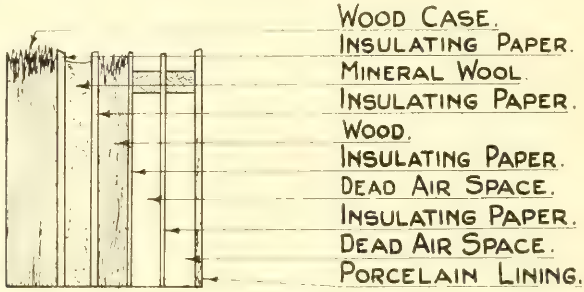


FIG. 195.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

also provides a place for the screws necessary to hold the lining in place. This construction is used on some of the best quality cabinets.

Fig. 197 shows a wall construction used for a cabinet with a composition lining. The lining must be well supported to

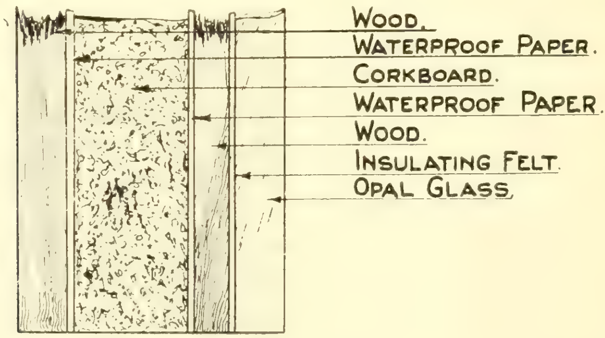


FIG. 196.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

prevent breakage in shipment. This type lining because of its large heat holding capacity, tends to keep the food compartment temperature uniform.

Fig. 198 shows a wall using fiber board insulation. This type cabinet is easily assembled at the expense of being poorly insulated. The dead air space near the lining would condense

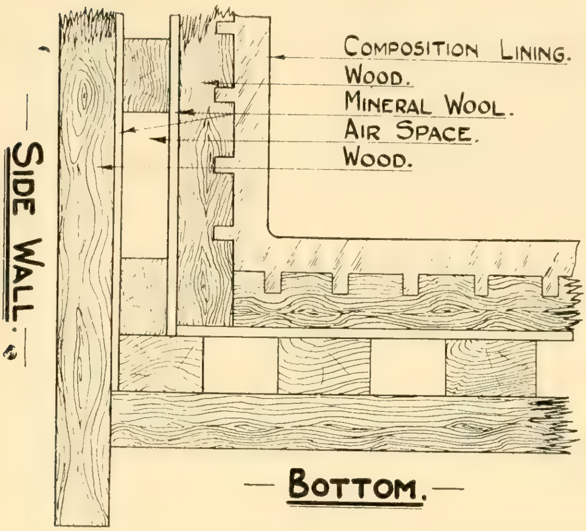


FIG. 197.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

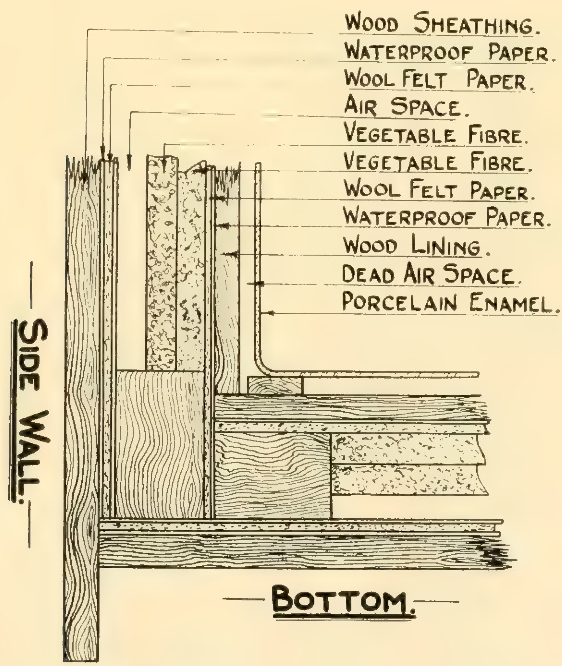


FIG. 198.—TYPICAL REFRIGERATOR WALL CONSTRUCTION

water vapor which would, in time, wet the insulation, thus lowering its efficiency. The solid wooden corners produce large heat losses by conduction from the outside case to the lining.

Linings.—The lining is a very important part of the household refrigerator. It represents from 10 to 25 per cent of the total cost of the refrigerator.

The lining material should have a smooth, hard, and preferably white surface. The surface should be stain and acid-proof and must not chip, crack, discolor, peel or craze. The surface should be such that dirt or grease will not adhere to it. The material itself should be free from joints and cracks, non-porous and should not absorb moisture or odors. It is also desirable to have a material suitable for making rounded corners.

Following is a list of the different linings in common use in refrigerator construction:

Baked white porcelain on sheet iron.
Solid porcelain.
Solid stone.
White opal glass.
Galvanized iron.
Enamel on steel.
Wood spruce, oak, pine.
Ceramic tile (floor).
Rust resisting metal.
Cement.

Porcelain on Iron Lining.—The standard lining for refrigerators is porcelain on iron. The sheet iron for the base is carefully selected, otherwise blisters may result. The sheet is cut, punched, and formed. The necessary welding is performed. It is then treated with acid to remove all grease and dirt. Sometimes other "pickling" baths are used. The lining is then dipped into a bath of blue porcelain. This porcelain composition usually consists of feldspar, borax, china clay, and other chemicals, in accordance with carefully prepared and tested formulas.

These materials are fused or melted in a smelting furnace. The melted mass is drawn off into a tank partly filled with

water. When it comes in contact with the water, it is instantly cooled and broken into small pieces of porcelain grit. This is placed in a revolving mill and ground as fine as flour. When taken from the mill it is thinned to cream-like consistency, and then taken to the dipping room where it is poured into metal vats.

The steel linings are first dipped into dark blue liquid, both inside and outside being covered with this first coat. This blue coat renders the surface impervious to rust and disintegration.

After the linings are dipped they are placed in drying chambers of high temperature where they remain for several hours to remove the moisture. If the moisture is not removed, the coating would run off when the lining is placed in the furnace.

After drying, these linings are placed on compressed air machinery in front of the furnace. The operator, who is forced by the intense heat to stand some distance from the furnace, by means of compressed air levers, raises the furnace doors and sends the linings forward in the furnace, where the porcelain is melted and fused onto the steel at a temperature of about 2000° F.

Two more coats of white porcelain are usually applied to the interior of the lining, the second being dried and melted on as above described before the third is applied.

This type lining gives a very good surface which fulfills most of all the various requirements. The surfaces, however, are not flat, as the baking process causes the metal to expand and warp. Considerable difficulty is experienced by the porcelain cracking at corners and welded joints.

Solid Porcelain Linings.—Solid porcelain linings are used in some of the better grade refrigerators. They are very heavy and require a solidly constructed cabinet to prevent breaking the lining in shipment. Most of the refrigerators using solid porcelain linings have an extra frame work of wood to make a rigid construction necessary with this type of lining. The walls are more than one inch thick.

The manufacture of solid porcelain linings is an art to which modern machinery has given very little assistance. The

clay is very carefully selected and is molded by hand in a form. These are placed in drying rooms for weeks where the temperature is gradually increased. The enamel is then applied with a brush; many coats are required with a period for drying between each coat, then several coats of glaze are applied. The linings are placed in the kiln and each one must be completely enclosed with fire brick. The baking lasts for about one week and a temperature of 2500° F. is reached. This entire process requires several months, so that this type lining is expensive to make, and is not well suited to quantity production.

The solid porcelain lining has a rather large heat storage capacity and the temperature in the food compartment will not change quickly with an increase or decrease in the amount of ice. These linings have an irregular surface on the insulation side so that it is necessary to apply a loose insulating material to fill up these irregularities.

White Opal Glass.—White opal glass lining has extensive use in refrigerators. The usual construction is to use the white opal glass lining on the sides, ceiling and doors. It is not suitable for the floor. Vitreous tile is usually used for lining the floors as it stands the rather severe service much better. Opal glass in common use is $\frac{7}{16}$ inch or $\frac{5}{16}$ inch thick. This type of lining presents a flat surface on both sides and this lessens insulation troubles. The corners and joints are usually covered with strips of metal. Other manufacturers use cement and in some cases wooden strips are used to cover the joints. White opal glass is used to line the doors in cabinets having solid porcelain linings.

Galvanized Iron.—Galvanized iron is not used to any great extent for linings except on a few of the cheaper boxes. It has been found that this material does not resist corrosion and rust as well as the other linings. Some manufacturers use galvanized iron for lining the ice compartments; however, it is losing favor even for this service.

Wood Linings.—Wood linings are being used more extensively even on some high-grade cabinets. An odorless

wood is used. The surface keeps dry. The wood lining must be carefully made to avoid crevices between the boards. Some manufacturers use a white enamel paint over the wood, while others use varnish.

General Considerations.—The one-piece porcelain or steel lining is gradually losing favor with the refrigerator manufacturers. This is probably due to the difficulty of making and handling these linings. When the porcelain coating cracks or chips at corners it cannot be repaired satisfactorily.

An additional disadvantage is experienced in assembling cabinets with the single-piece lining. The insulation and outer walls of the cabinet must be built around the lining.

Sheet porcelain is now being used extensively for lining cabinets. Metal strips are used to hold the sheets in place and to seal around the corners. With this method of construction, it is possible to make the various cabinet walls on benches in quantities. The final assembly of the cabinet is then a simple process, requiring very little labor. This method of construction is preferable for quantity production.

Outer Case Construction.—The outer wall of most refrigerators is of wood. The best wood for this purpose is ash. Oak, fir, spruce, and pine are also used to some extent.

Most manufacturers use a panel wood construction for the outer case. These panels have a clearance at the edges great enough to allow for expansion and contraction, due to temperature and humidity changes. A careful study of these panels in service will show that they actually expand or contract, frequently breaking the paint or finish around the edge of the panel.

Some advantages of panel construction are:

1. Constructed of short pieces of light boards reducing waste lumber.
2. Less weight.
3. Heavy wall at corners where it is needed for structural strength.
4. Panels properly proportioned give an attractive appearance.
5. Reduces warping troubles.

Some of the more expensive cabinets use a veneer panel which it is claimed eliminates warping. Metal outer cases are used, such as porcelain enamel on steel, baked white enamel on steel, sheet steel zinc plated with a white baked enamel surface, white opal glass and monel metal.

Some troubles are experienced with the metal boxes in joining the lining with the outer case at the doors. There is usually a large heat loss here, and trouble with the moisture collecting on the outer metal case around the doors. Sheet steel is being used extensively for the outer case, the usual finish is white duco enamel.

Doors.—The door construction is a very important part of refrigerator design. The frame for the door and the door opening is usually of wood several inches thick. This double wooden frame has a poor heat insulating property, which is less than half that of corkboard. Figs. 199, 200, 201, and 202 show methods of refrigerator door construction in common use.

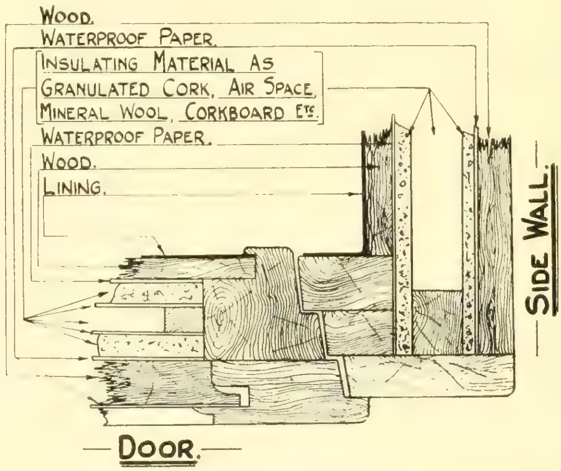


FIG. 199.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION

The insulation is usually less on the front of a refrigerator than on any other side. This has been determined by tests using thermo-couples on the outside surface of the cabinet to obtain the surface temperature. Another indication of insuf-

ficient insulation around the doors is the fact that moisture condenses on these parts first when there is a high room humidity.

The door heat loss is especially large when metal is used to line the door frame or the edges of the door itself. There is need for a new material to make the door opening frame and the door frame. Wood does not have sufficient heat

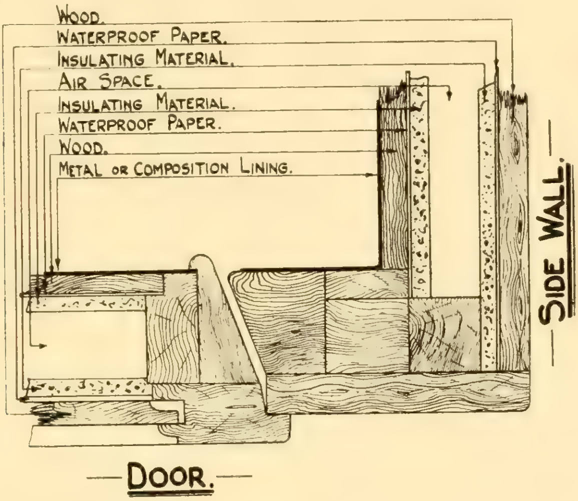


FIG. 200.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION.

insulating property. Following are some of the more important points to be considered in door design:

1. Increased heat loss by conduction through solid or metal framework.

2. Heat loss due to doors not closing tightly causing too rapid ventilation with outside air. This loss is especially large if the door does not fit properly at the top and bottom and varies according to the room or environment humidity, being greater with higher humidity.

3. Damage to the finish and the exterior surface around the doors caused by the condensation of moisture.

4. Warped doors due to constant changes in moisture, temperature and humidity, and the difference in these conditions on the outside and inside surfaces of the door.

5. Heat loss due to improper design of angle and clearance allowing large air wedge between edge of door and frame.

The refrigerator door has to stand a severe surface condition of humidity and temperature. The humidity frequently attains such conditions as 90 per cent on one side and 40 per cent on the other. The temperature usually has a differential of from 20 to 40 degrees on the outside and inside of the box. Ash is one of the best woods to use for this severe service.

Various kinds of gaskets are available for making a tight seal around the door. Some of the materials for this purpose are rubber, felt, rubberized cotton, and thin copper metal strips. The high grade boxes do not depend upon gaskets for a close fit. Most gaskets are affected by moisture or lose their resiliency after a few months of service. Gaskets are used very effectively on large cold storage doors where it is not practical or necessary to make a good wood-to-wood fit. When a well-made door is fitted properly it will close tightly on all four sides against a strip of ordinary writing paper.

Some manufacturers use a series of steps in the door and

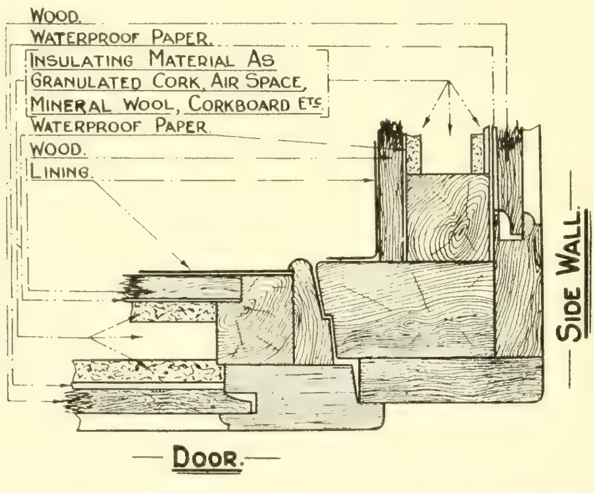


FIG. 201.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION.

the door frame. The better boxes have only one or two steps and fit well against the outside surface of the box. No attempt is made to fit closely between any of the other surfaces.

The door-facing strip should have a slope on the side of the door opposite the hinges. This slope is usually applied to

the other three sides of the door and door opening, although this is entirely unnecessary except for symmetry. The angle of this slope is easily determined by the radius from the center of the hinge to the inside of the door stop on the opposite side.

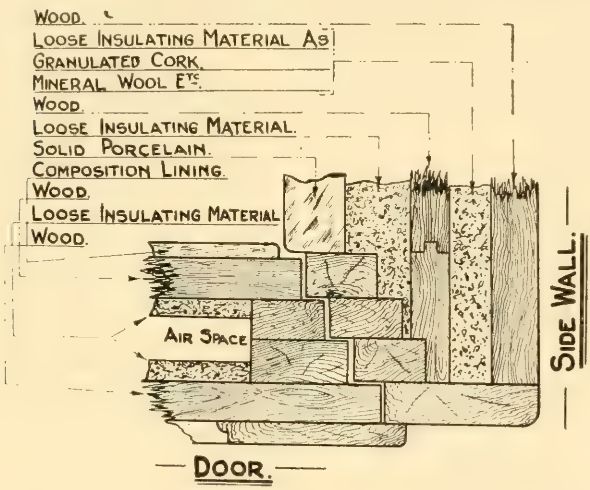


FIG. 202.—TYPICAL REFRIGERATOR WALL AND DOOR CONSTRUCTION.

The door construction is one of the most difficult problems encountered in making an all-metal box. Even at a room humidity of 50 or 60 per cent, condensation will probably form around the doors of an all-metal box. This may damage the exterior finish of the metal.

The door to the ice compartment should always have an opening at least 12 inches wide. This will allow the thickest end of a manufactured cake of ice, 11½ inches on a 300-pound size and 11⅝ inches on a 400-pound cake, to enter without chipping.

Shelves.—The shelf arrangement is an important design feature frequently neglected in refrigerator construction.

The ratio of shelf area to food storage volume is a good method of checking this part of the design.

Tables LXII and LXIII show that the top icer and ell type refrigerators have practically the same shelf surface for the same rated ice capacity.

Shelves are usually made of small mesh wire heavily tinned. Glass shelves are used to a limited extent. Some

TABLE LXII.—SHELF AREA OF TOP ICER REFRIGERATORS.

Rated Ice Capacity (Pounds)	50	75	100
	Shelf Area Square Feet		
Box 1	4.8	6.2	7.0
" 2	4.2	5.1	5.9
" 3	4.9	5.4	7.2
" 4	4.0	5.6	8.1
" 5	3.4	4.3	6.1
" 6	3.6	6.5	7.8
" 7	5.2	5.3	5.4
Average	4.3	5.6	6.8

All of these boxes have three shelves.

shelves are constructed of small steel bars welded together into a unit and heavily tinned. Some of the advantages of wire shelves are:

1. Cheapness of construction.
2. Light weight.
3. Easily removed and cleaned.
4. Allow free air circulation.
5. Permit seeing through them to locate articles underneath.
6. Surface not damaged by heavy food containers.
7. Do not rust or corrode readily.

TABLE LXIII.—SHELF AREA OF ELL TYPE OF REFRIGERATORS.

Rated Ice Capacity (Pounds)	75	100	200
	Shelf Area Square Feet		
Box 1	5.8	8.7	16.0
" 2	6.6	8.3	10.5
" 3	5.3	6.0	12.0
" 4	6.2	6.5	16.0
" 5	5.6	7.8	10.0
" 6	5.0	8.5	16.2
" 7	4.0	7.4	18.0
Average	5.5	7.6	14.1

Some refrigerators are made with shelf supports adjustable for height. It has been found in actual service that this

feature is not used, as the owner evidently does not appreciate the advantage of spacing the shelves to conform with certain requirements.

TABLE LXIV.—INSULATORS USED IN REFRIGERATORS.

Wood	42
Air Space	28
Paper	28
Granulated Cork	13
Mineral Wood	12
Corkboard	8
Flax Composition	6
Felt Paper	2
Cocoa Fiber	1
Vegetable Fiber	1
Eel Grass	1
Hairfelt	1
Wood Fiber	1
Sea Grass	1

The shelf spacing in cabinets using mechanical refrigeration is usually closer than on refrigerators using ice. This close spacing is permissible because of the colder temperature and more active circulation.

Materials for Refrigerators. — The insulating materials used in 50 standard refrigerators are listed in Table LXIV.

The foregoing indicates the number of times each insulating material was used in the construction used by 50 different manufacturers.

Table LXV shows the woods used in 50 standard refrigerators for outside case and linings:

TABLE LXV.—WOODS USED IN REFRIGERATORS.

Oak	21
Ash	13
Fir or Spruce	7
Yellow Pine	1
White Pine	1
Black Ash	1
Poplar	1
Cypress	1
Birch	1

Table LXVI gives a list of some of the woods which are suitable for refrigerator construction. The botanical name and locality where such wood grows are included also.

TABLE LXVI.—WOODS MOST SUITABLE FOR REFRIGERATORS.

Common Name	H = Hard S = Soft or Coniferous	Botanical Name	Locality Where Grown
Ash, black	H	Fraxinus nigra	Mich. Wis.
Ash, Oregon	H	Fraxinus oregona	Oregon
Ash, white, forest grown	H	Fraxinus americana	Ark. W. Va.
Ash, white, second growth	H	Fraxinus americana	New York
Basswood	H	Tilia americana	Penn. Wis.
Beech	H	Fagus atropunicea	Ind. Penn.
Birch, sweet	H	Betula lenta	Pennsylvania
Birch, yellow	H	Betula lutea	Penn. Wis.
Birch, black	H		
Birch, white	H		
Butternut	H	Juglans cinerea	Tenn. Wis.
Butternut, white walnut	H		
Buttonwood, sycamore			
Chestnut	H	Castanea dentata	Md. Tenn.
Cottonwood	H	Populus deltoides	Missouri
Cottonwood, black	H	Populus trichocarpa	Washington
Cypress, bald	S	Taxodium distichum	La. Mo.
Cypress, yellow	S	Chamaescyparis nootkatenis	Oregon
Douglas fir—also called Oregon pine	S	Pseudotsuga taxifolia	Wyoming. Mo. Wash. Ore.
Dogwood, flowering	H	Cornus florida	Tennessee
Dogwood, western	H	Cornus muttallii	Oregon
Elm, gray	H		
Fir, white	S	Abies concoler	
Fir, red	S		
Fir, yellow	S		
Gum, black	H	Nyssa sylvatica	Tennessee
Gum, red	H	Liquidambar styraciflua	Missouri
Gum, sap	H		
Hackberry	H	Celtis occidentalis	Wis. Ind.
Hemlock, black	S	Tsuga mertensiana	Montana
Hemlock, eastern	S	Tsuga canadensis	Tenn. Wis.
Hemlock, western	S	Tsuga heterophylla	Washington
Locust, black	H	Robinia pseudacacia	Tennessee
Locust, honey	H	Gleditsia triacanthos	Mo. Ind.
Maple, Oregon	H	Acer macrophyllum	Washington
Maple, red	H	Acer rubrum	Penn. Wis.
Maple, silver	H	Acer saccharinum	Wisconsin
Maple, sugar	H	Acer saccharum	Ind. Pa. Wis.
Maple, rock	H		
Maple, hard	H		
Maple, soft	H		
Oak, California black	H	Quercus californica	Cal. Oregon
Oak, canyon live	H	Quercus chrysollpsis	California
Oak, chestnut	H	Quercus Prinus	Tennessee
Oak, cow	H	Quercus nichaurii	Louisiana
Oak, laurel	H	Quercus laurifolia	Louisiana
Oak, Pacific post	H	Quercus garryana	Oregon
Oak, post	H	Quercus minor	Ark. La.

TABLE LXVI.—WOODS MOST SUITABLE FOR REFRIGERATORS—(*Cont'd*)

Common Name	H = Hard S = Soft or Coniferous	Botanical Name	Locality Where Grown
Oak, red	H	Quercus rubra	Ark. La. Ind. Tennessee
Oak, Spanish highland	H	Quercus digitata	Louisiana
Oak, Spanish lowland	H	Quercus pagodaefolia	Louisiana
Oak, white	H	Quercus alba	Ark. La. Md.
Oak, willow	H	Quercus phellos	Louisiana
Oak, yellow	H	Quercus velutina	Ark. Wis.
Oak, English	H		
Pine, jack	S	Pinus heterophylla	Florida
Pine, longleaf	S	Pinus palustria	Fla. La. Miss.
Pine, Norway	S	Pinus resinosa	Wisconsin
Pine, pitch	S	Pinus rigida	Tennessee
Pine, shortleaf	S	Pinus echinata	Ark. La.
Pine, sugar	S	Pinus lambertiana	California
Pine, table mountain	S	Pinus pungens	Tennessee
Pine, western white	S	Pinus monticola	Montana
Pine, western yellow	S	Pinus ponderosa	Colo. Mont. Ariz. Wash. Calif.
Pine, white	S	Pinus strobus	Wisconsin
Pine, northern yellow	S		
Pine, southern yellow	S		
Pine, Georgia	S		
Pine, spruce	S		
Poplar, yellow	H	Liriodendron tulipifera	Tennessee
Poplar, white	H		
Poplar—also called whitewood	H		
Redwood, California			
Sassafras	H	Sassafras sassafras	Tennessee
Spruce, Engelmann	S	Picea engelmanni	Colorado
Spruce, red	S	Picea rubens	N. H. Tenn.
Spruce, litka	S	Picea sitchensis	Washington
Spruce, white	S	Picea canadensis	N. H. Wis.
Sumac, staghorn	H	Rhus hirta	Wisconsin
Sycamore	H	Platanus occidentalis	Ind. Tenn.
Tamarack	S	Larix laricina	Wisconsin
Willow, western	H	Salix lasiandra	Oregon

Ice Capacity of a Refrigerator.—The ice capacity of a refrigerator is an arbitrary figure at the best, inasmuch as the pieces of ice that are put into it vary considerably in size and so make more or less waste space. Ice capacities in refrigerators are usually figured in the following way:

The cubic inches of ice chamber divided by 1,728 gives total cubic feet and this multiplied by 57.5, which is the weight

of a cubic foot of ice, gives the total ice capacity in terms of pounds of ice. From this deduct 25 per cent, considered as a fair allowance for waste space or irregular shaped ice, and the remainder is the figure of ice capacity of a refrigerator.

TABLE LXVII.—RATED ICE CAPACITIES OF REFRIGERATORS.
Summary of Data on 473 Different Standard Models. (Side Icers.)

Total Inside Volume Cubic Feet.	Average Rated Ice Capacity Pounds.	Maximum Rated Ice Capacity Pounds.	Minimum Rated Ice Capacity Pounds.
4—5	58	75	40
5—6	81	110	50
6—7	93	110	50
7—8	103	125	50
8—10	126	200	65
10—12	142	200	75
12—16	177	250	85
16—20	204	300	150
20—24	244	375	170
24—30	284	350	235
30—40	310	425	190
40—60	420	550	300

Table LXVII gives the rated ice capacities of refrigerators obtained from the data on 473 different standard models of side icer refrigerators. Data are given for refrigerators having volumes varying from 4 cubic feet to 60 cubic feet. It is interesting to note the difference in the minimum rated ice capacity, average rated ice capacity, and the maximum rated ice capacity. Table LXVIII gives similar rated ice capacities from data on 88 different models of the top icer lift lid icing door construction.

TABLE LXVIII.—RATED ICE CAPACITIES OF REFRIGERATORS.
Summary of Data on 88 Different Models (Top Icers, Lift Lid Icing Door).

Total Inside Volume Cubic Feet.	Average Rated Ice Capacity Pounds.	Maximum Rated Ice Capacity Pounds.	Minimum Rated Ice Capacity Pounds.
3—4	56	120	40
4—5	69	151	65
5—6	92	117	75
6—7	106	133	69
7—8	133	188	100
8—9	105	110	100
9—10	124	150	100
10—11	150	150	150

Table LXIX gives additional rated ice capacities of refrigerators. The data in this table was obtained from an average

of information on 282 different models of the top icer construction, including both lift lid and front door icers.

TABLE LXIX. RATED ICE CAPACITIES OF REFRIGERATORS.
Summary of Data on 282 Different Models (Top Icers Including Lift Lid and Front Door Icers.)

Total Inside Volume Cubic Feet.	Average Rated Ice Capacity Pounds.	Maximum Rated Ice Capacity Pounds.	Minimum Rated Ice Capacity Pounds.
3—4	62	120	40
4—5	74	151	55
5—6	85	135	60
6—7	101	190	65
7—8	122	188	60
8—9	121	165	75
9—10	144	175	100
10—11	165	224	125
11—12	142	220	110
12—15	194	235	160
15—22	224	420	150

Table LXX gives the rated ice capacities of refrigerators obtained from 194 different standard models of the top icer construction, with the icing door on the front.

TABLE LXX.—RATED ICE CAPACITIES OF REFRIGERATORS
Summary of Data on 194 Different Standard Models. (Top Icers, Icing Door on Front).

Total Inside Volume Cubic Feet.	Average Rated Ice Capacity Pounds.	Maximum Rated Ice Capacity Pounds.	Minimum Rated Ice Capacity Pounds.
3—4	59	100	50
4—5	81	104	55
5—6	95	135	60
6—7	113	190	65
7—8	120	176	60
8—9	125	165	75
9—10	154	175	140
10—11	172	224	125
11—12	142	220	110
12—15	194	235	160
15—22	224	350	150

Table LXXI gives some interesting information on ice refrigerators of the ell type construction. Three sizes, 75, 100, and 200 pounds rated ice capacity, are included. It is interesting to note the variation of shelf area, per cent of ice storage space used at rated ice capacity, per cent of inside volume used for ice storage, and the ratio of the shelf area to the food storage volume. Similar ice refrigerator cabinet data

TABLE LXXI.—ICE REFRIGERATOR CABINET DATA: ELL TYPE.

Rated Ice Capacity	Pounds	75	100	200
Outside Dimensions	Width Inches	32.0	34.6	43.4
	Depth	18.6	20.6	24.6
	Height	43.0	46.4	56.0
Ice Compartment	Width Inches	12.4	13.1	17.3
	Depth	13.6	15.0	18.9
	Height	17.3	19.7	26.1
Total Volume Overall	Cu. Ft.	14.9	19.2	35.5
Food Storage Space	Cu. Ft.	3.6	5.0	10.5
Ice Storage Space	Cu. Ft.	1.7	2.2	5.9
Shelf Area.	Sq. Ft.	5.5	7.2	14.1
Percent Ice Storage Space used at Rated Ice Capacity		77.1	79.6	59.1
Percentage of Inside Volume for Ice Storage		32.	31.	36.
Shipping Weight (Pounds)		214	293	477
Ratio of Shelf Area to Food Storage Volume		1.53	1.45	1.34

This table is computed from ten standard refrigerators with baked porcelain one piece linings.

are given in Table LXXII for refrigerators of the top icer construction, having rated ice capacities of 50, 75, and 100 pounds. These data are shown graphically by Figs. 203 and 204.

TABLE LXXII.—ICE REFRIGERATOR CABINET DATA: TOP ICER.

Rated Ice Capacity	Pounds	50	75	100
Outside Dimensions	Width Inches	23.4	26.3	29.1
	Depth	16.3	17.7	18.9
	Height	41.4	43.7	48.1
Ice Compartment	Width Inches	15.8	18.9	21.7
	Depth	10.8	12.4	13.3
	Height	10.3	11.7	12.9
Total Volume Overall	Cu. Ft.	9.1	12.3	15.3
Food Storage Space	Cu. Ft.	1.94	2.9	3.8
Ice Storage Space	Cu. Ft.	1.02	1.59	2.15
Shelf Area	Sq. Ft.	4.3	5.6	6.8
Percent Ice Storage Space used at Rated Ice Capacity		85.8	82.4	81.3
Percent of Inside Volume used for Ice Storage		34.5	35.5	36.2
Shipping Weight, pounds		143	173	215
Ratio of Shelf Area to Food Storage Volume.		2.22	1.93	1.79

This table is computed from ten standard refrigerators with baked porcelain one piece linings.

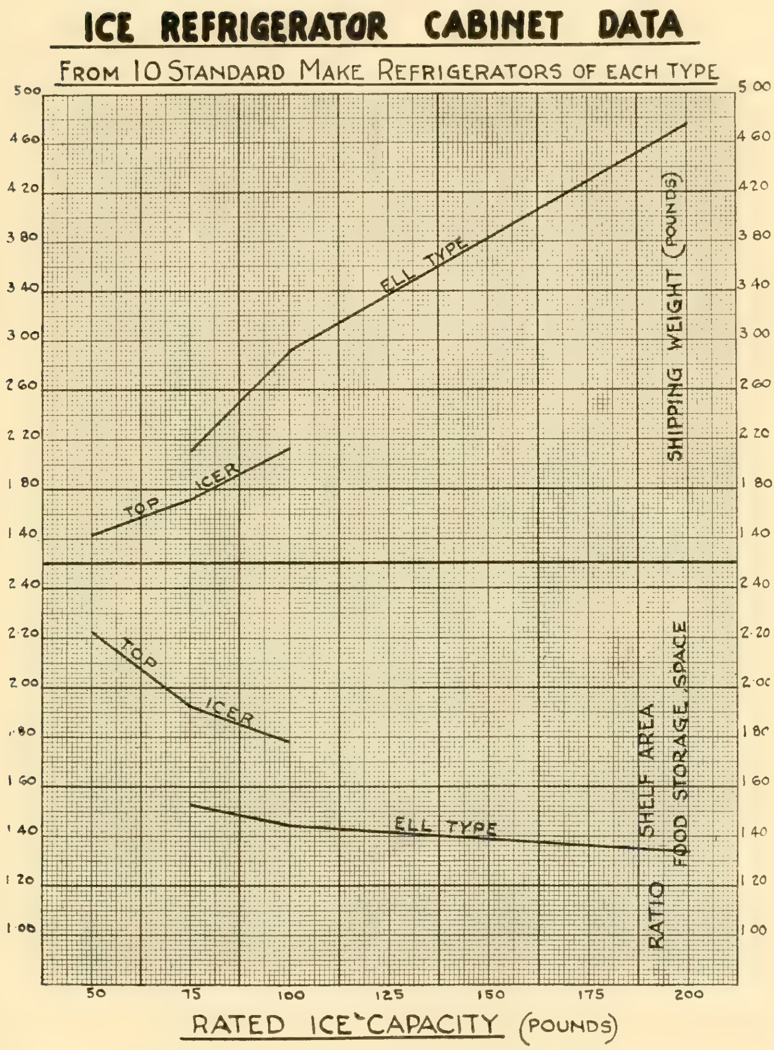


FIG. 203.—ICE REFRIGERATOR CABINET DATA.

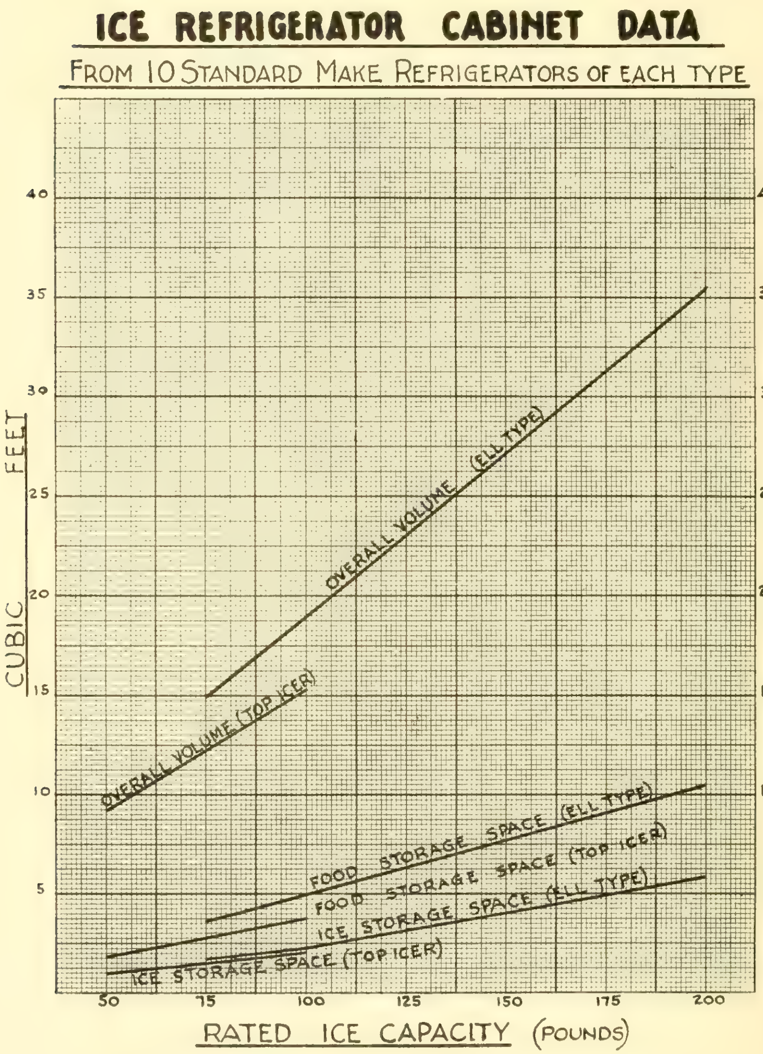


FIG. 204.—ICE REFRIGERATOR CABINET DATA.

CHAPTER X

OPERATION OF ICE REFRIGERATORS.

Temperature.—The usual method of solving the household refrigeration problem is by the use of ice in any of the standard type refrigerators.

The refrigerator using ice will have a temperature in the food storage compartments 20 to 30 degrees lower than room temperature.

The better type refrigerators with very good insulation will approach the 30 degree temperature difference when there is a good supply of ice.

A temperature difference of about 10 degrees between the coldest and warmest part of the food storage compartments is necessary to insure good circulation of the enclosed air. In this way heat is transferred from the food to the ice compartment. This heat transfer is mostly by convection, the circulating air acting as the carrier.

The coldest part of the food storage space is the lower part directly under the ice compartment. The circulating air becomes warmer as it rises in the food compartment, absorbing heat from the walls, food and food containers.

The temperature in the warmest part of a refrigerator should never be higher than 50° F. for the proper preservation of food.

The temperature of the coldest air dropping into the food compartment is usually between 40° and 50° F., depending

upon the amount of ice, the type and construction of the box and the temperature of the air entering the top of the ice compartment. The melting ice, of course, is always at a temperature of 32° F.

It is necessary to have a well-insulated refrigerator to obtain by the use of ice a temperature suitable for the storage of perishable food products.

The desirable temperatures which are recommended for refrigerators by different authorities are given in Table LXXIII. The authorities quoted are as follows: New York Tribune Institute, United States Department of Agriculture, Dr. L. K. Hirschberg, and Dr. John R. L. Williams.

It will be further noted that the recommendations for the most desirable temperatures for refrigerators varies from 40° to 50°, with 45° as an average.

Operating Conditions.—The effect of room temperature on the amount of refrigeration required for a refrigerator can be easily approximated.

For example, if the average operating condition is at 45° F., food compartment temperature in a 70° F. room, the temperature difference is 25° F. The increase in refrigeration required in higher temperature rooms would be as follows:

Food Compartment Temperature	Room Temp.	Temperature Diff.	Increase in Refrigeration required per cent
45	70	25	..
45	80	35	40
45	90	45	80

Usually at a higher room temperature the food compartment temperature will be higher and the increase in refrigeration will be somewhat less than the amount indicated by this table.

Circulation of Air.—There is a constant circulation of air in refrigerators as long as the ice lasts. For the preservation of food, it is equally as necessary to have good air circulation as it is to maintain a low temperature in the food compartment. No matter how cold the air is, it will not preserve the food properly unless the air is in active circulation.

TABLE LXXIII.—DESIRABLE TEMPERATURE FOR REFRIGERATORS.

Temperature Recommended Deg. F.	Authority	Published in	Extracts.
40°—50°	New York Tribune Institute	New York Tribune	40° to 50° averaging 45°; these are the aims of a super refrigerator. A temperature of 40° to 45° is considered ideal for home refrigerator purposes. It should not go above 50°.
50° or less	U. S. Department of Agriculture	Farmers' Bulletin No. 1207	The best temperature for keeping milk is 50° or less. If a thermometer placed inside a refrigerator registers more than 50°, the fault cannot be laid entirely to the quality of the milk. Even a temporary rise in the temperature of milk will help the development of bacteria.
45° or less	Dr. L. K. Hirshberg	Chicago Evening Post	Refrigerators, ice boxes, cold storage, etc., which keep food well below 45°, help to keep it free of any great increase and growth of bacteria.
40°—50°	U. S. Department of Agriculture M. H. Abel	Farmers' Bulletin No. 375	If on a warm summer day you put your hand into an ice box well filled with ice you may think that the temperature is very low, and yet it is in all probability nearer 50° than 40° F. The ice box no matter how well cooled, is and must be damp, and dampness is one of the requirements for bacterial growth.
50° or less	U. S. Department of Agriculture J. T. Brown	Bulletin No. 98	Proper refrigeration is of the utmost importance in the preservation of milk. Without thorough cooling it is impracticable to keep milk for any considerable length of time in a condition that would justify its use for household purposes. It should be cooled to 50° F. or below.
50° or less	John R. Williams, M. D.	Report at 3rd. Int. Ref. Congress	A box or room for the storage of perishable foods to be at all efficient, must have a temperature not in excess of 50° F., preferably below 45° F.

It is a well-known fact that cold air falls while warm air rises. The cold air cooled by contact with the surface of the ice is carried down by its own weight, forcing ahead of it warmer air in other parts of the food compartment. This warmer air taking heat from the food, food containers and walls, rises to the top of the refrigerator where it passes into the ice compartment. It is cooled again and repeats this cycle, thus establishing continuous circulation.

Circulation is very important as it distributes the cool air to all parts of the refrigerator. The circulating air in passing the ice loses some of the moisture and the odor which it has taken up from the food.

The opening for the air to enter and leave the ice compartment should be as large as possible as the maximum velocity of the circulating air is relatively quite low.

Government tests on nine standard refrigerators of average quality or better, give the rate of air circulation as 10.1 to 21.4 cubic feet per minute at 60° F.

Melting ice has a temperature of 32° and the best circulation which can be obtained will not keep the warmest part of the food compartment at a temperature less than 50° in a room of 90°. Therefore, it is desirable to have as rapid a circulation as possible.

A good indication of the rate of air circulation in the refrigerator is the difference in temperature between the lower or coldest, and the upper or warmest part of the food compartment. This value is usually 10° or 15° in the average household refrigerator of from 50 to 150 pounds ice capacity.

Some typical refrigerator boxes are shown in Figs. 205 and 206 with arrows indicating the path of the circulating air. A gain in efficiency can be made by having the warm air flues against the exterior wall getting the path of the cold air in the center of the box. This will make an appreciable saving in the amount of ice used.

It is advantageous to have the ice compartment so constructed that the ice will never project above the lower level of the warm-air opening into this compartment. Careful tests have shown that there is a real gain in efficiency by doing this.

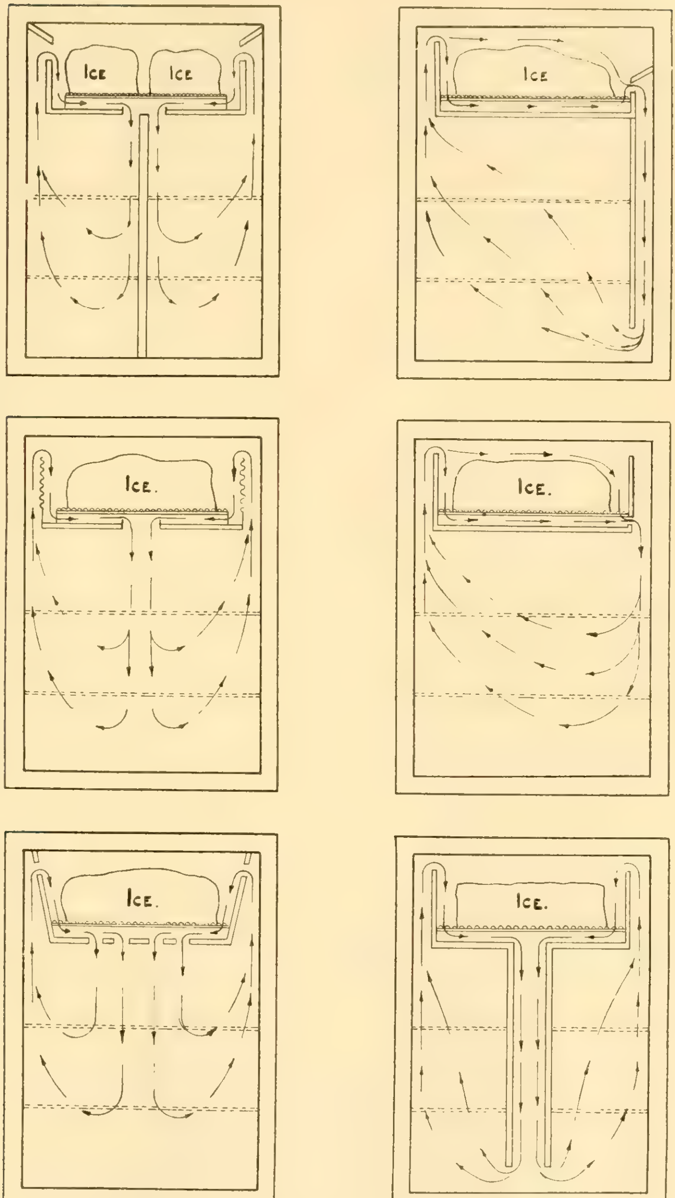


FIG. 205.—AIR CIRCULATION IN REFRIGERATORS.

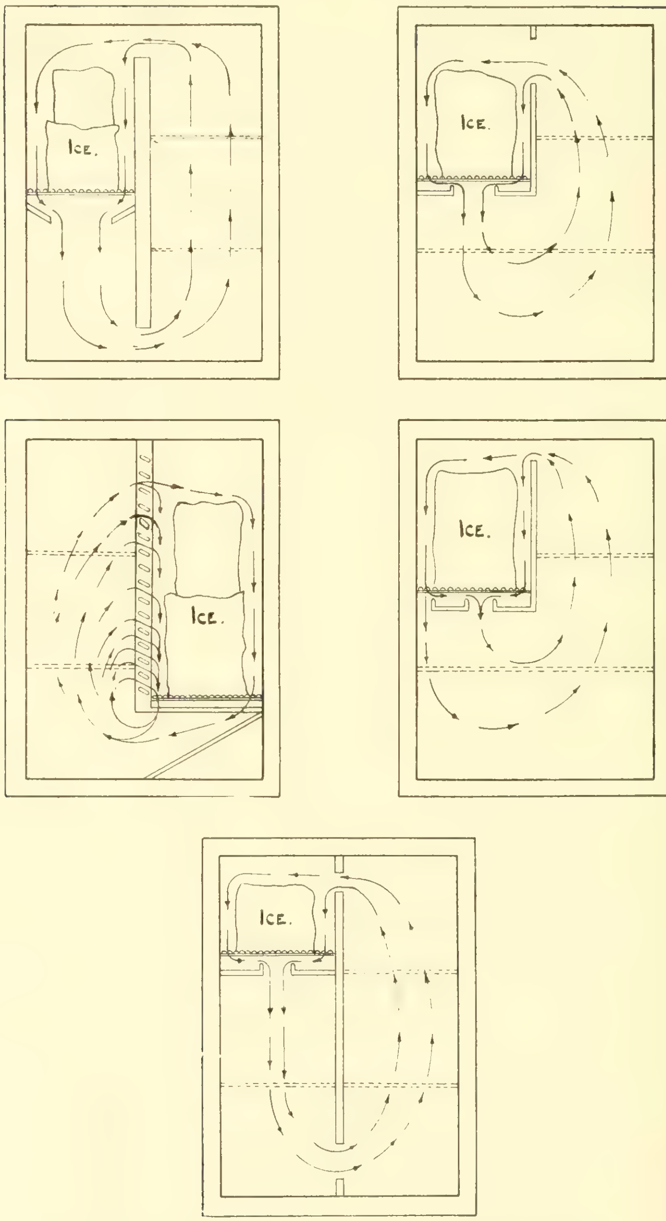


FIG. 206.—AIR CIRCULATION IN REFRIGERATORS.

Good air circulation in a refrigerator prevents the mixing of food tastes to a large extent. Foods such as onions, lemons, and brussels sprouts, which have the property of mixing their tastes with other foods, should be placed in the upper part of the refrigerator as most of the gases will then be absorbed by the water on the surface of the ice.

Circulation in Ice Chambers. — Fig. 207 shows various methods of producing circulation in a refrigerator.

In the upper figure there is no baffle plate. Local circulation is produced near the surface of the cake of ice. This condition is not satisfactory for storing food as the humidity would be unusually high in the food storage compartment. This construction causes food odors and favors high temperatures.

The center figure shows a metal baffle plate. This improves the condition in the food compartment. The baffle plate would probably be covered with condensation on the food compartment side. This construction would insure lower and more uniform temperature in the food compartment than obtained with the previous method.

The lower figure shows an insulated baffle plate. This is the ideal construction, affording a still better condition of lower and more uniform temperature, lower humidity and good air circulation. The baffle plate usually requires insulation equivalent to one-half or one-third of that used in the walls of the cabinet.

Air Circulation Tests.—A simple method of measuring the rate of air circulation is to place an anemometer in a flue opening in various positions to find the average velocity. Knowing the velocity of the air through this opening and its area, the amount of air circulating can be calculated.

A heat balance method is sometimes used to determine the approximate rate of circulation. The heat loss through the walls is determined by an ice-melting test. It is then assumed that this loss is due to the circulating air carrying the heat by convection from the walls of the cabinet to the ice. The heat transfer by radiation and conduction from the walls to the ice is relatively small and therefore not consid-

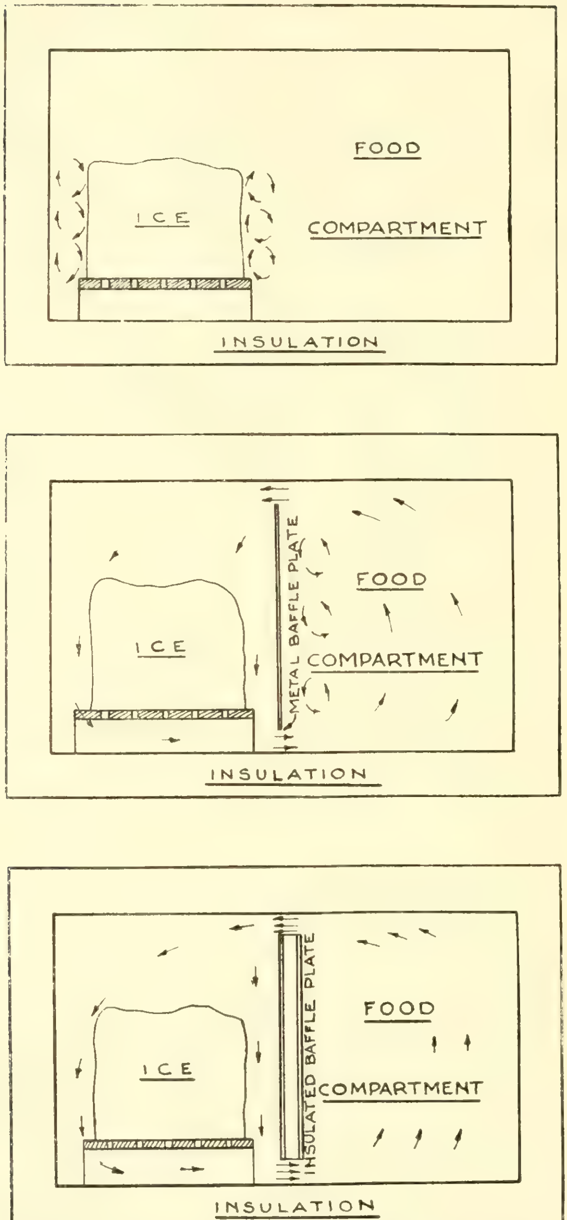


FIG. 207.—AIR CIRCULATION IN ICE CHAMBERS.

ered. The temperature difference of the circulating air entering and leaving the ice compartment can easily be determined by thermometers in the flue openings.

The following equation will approximate the amount of air circulating per hour:

$$\text{Pounds of Ice Melted per hour} \times 144 = \text{Pounds of Air circulating per hour} \times \text{Specific Heat} \times \text{Temp. Difference}$$

$$\text{Pounds of Air circulated per hour} = \frac{\text{Pounds of Ice Melted per hour} \times 144}{0.24 \times \text{temp. difference of air entering and leaving ice compartment}}$$

The humidity of the circulating air will have an effect on its heat-carrying capacity. However, this is a relatively unimportant factor and is not usually considered, as this difference in the final result is less than other variables which are not taken into account.

Air circulation tests on a well-insulated cabinet cooled with a mechanical system show that the circulation through the food compartment varies from 1.0 to 5.0 feet per minute. As the flue opening has an area equivalent to 1/10 of the food compartment, the rate of air circulation through the flue opening varies from 10 to 50 feet per minute.

Humidity.—Humidity is the water vapor in the air. Atmospheric air always contains a certain amount of water vapor mixed with it. Air at a certain temperature and pressure can contain a definite amount of water vapor. When this amount is exceeded, the excess water vapor will condense.

Perfect refrigeration depends as much upon dryness as it does upon cold. It is very essential to have a circulation of so-called "dry" air in order to properly preserve food in a refrigerator. It is just as important that the humidity be low as it is that the temperature be low. A practical example is the poor results obtained by keeping foods in the ordinary ice chest where there is considerable moisture and poor air circulation. Foods will spoil more rapidly in an ice chest than in the ordinary refrigerator, even though the temperature in the ice chest be as low or even lower than that in the refrigerator.

Most cellars are unsuitable for storing perishable foods because of the dampness or high humidity in the air.

One hundred cubic feet of air at atmospheric pressure can contain the definite amounts of water vapor at the temperatures given in Table LXXIV.

TABLE LXXIV.—WATER VAPOR IN AIR.

Temperature Deg. F.	Weight of Water Vapor per 100 cu. ft. of air.
32	0.0304
40	0.0410
50	0.0587
60	0.0827
70	0.1145
80	0.1564
100	0.2850

The amount of water vapor which the air can contain increases with the temperature and decreases with pressure.

Relative humidity is the per cent of water vapor actually present in the air in relation to the maximum amount of water vapor which the air can contain at a definite pressure and temperature.

Example: Suppose atmospheric air at 80° F. had a relative humidity of 60 per cent. The amount of water vapor in each 100 cubic feet of air would be

$$\frac{60}{100} \times 0.1564 \text{ or } 0.09384 \text{ pounds}$$

The relative humidity inside a refrigerator is highest where the cold air drops out of the ice compartment. The relative humidity is lowest at the top of the food compartment where the warm air enters the ice compartment. There is a gradual increase between these two points as the circulating air becomes warmer.

The average relative humidity within the food storage compartment in refrigerators using ice is from 50 to 80 per cent. The humidity is increased by placing in the refrigerator foods or liquids which have a high moisture content.

In summer the humidity in the kitchen is usually higher than in the refrigerator. Opening the refrigerator doors will then temporarily increase the humidity inside.

Example: Assume a refrigerator of 10 cubic feet inside capacity containing 50° air at 60 per cent relative humidity. The kitchen temperature is 80° with 80 per cent humidity. The refrigerator doors are left open long enough to replace half the cold dry air with warm vapor laden room air. What is the loss in refrigeration by this change?

Cool 5 cu. ft. dry air 80° to 50°:
5 cu. ft. or $5 \times 0.071 = 0.355$ pounds.
$0.355 \times 0.238 \times 30 = 2.5347$ B.t.u.

Amount of water vapor cooled:
At 80 degrees 0.001564 pounds per cu. ft.
$5 \times 0.001564 \times 0.80 = 0.006256$ lbs.

Cooling water vapor (80° to 50°):
$30 \times 0.006256 = 0.18768$ B.t.u.

Amount of water vapor condensed:
At 50° and 60 per cent humidity
$5 \times 0.000587 \times 0.60 = 0.001761$ pounds
$0.006256 - 0.001761 = 0.004495$ pounds

Heat required to condense 0.004495 lbs. of water vapor:
$0.004495 \times 1000 = 4.495$ B.t.u.

Total heat loss:

Cooling air	2.5347 B.t.u.
Cooling water vapor	.1877 B.t.u.
Condensing water vapor	4.495 B.t.u.
Total	7.2174 B.t.u.

This problem shows the important part humidity plays in ordinary household refrigeration problems.

The results of the humidity tests in a mechanical household refrigerator are shown in Table LXXV. From the second and third columns of Table LXXV, it will be observed that the food compartment relative humidity increased gradually as the relative humidity of the room increased, although not in the same proportion. The temperatures of the room, top of food compartment, and bottom of food compartment were maintained approximately constant during the test.

Humidity Test.—This test was made on a well-insulated cabinet, cooled with a brine tank. The temperature of the brine during the test varied from 18° F. to 22° F. Several tests similar to this one indicate that the relative humidity of the food compartment can be approximately determined by computation. It is only necessary to know the tempera-

ture of the cooling element and the temperature of the food compartment. The air in contact with the cooling element is nearly saturated with moisture.

TABLE LXXV.—HUMIDITY TEST ON A MECHANICAL HOUSEHOLD REFRIGERATOR.

To determine the effect on the food compartment humidity when the humidity in the room is gradually increased.

	Percent Relative Humidity		Temperature		
Time	Room	Food Compartment—Bottom	Room	Top Food Compartment	Bottom Food Compartment
9:30 A. M.	28	28	80	54.5	44
9:45	35	29	80	54	44
10:15	40	34	81	53.7	44
10:45	45	40	80	53.5	43.6
11:15	50	42	80	53.3	43
11:45	55	45	80	53.1	42.5
1:30 P. M.	60	48	80	52.8	42.5
2:00	65	49	80	52.8	42.5
2:30	70	50.5	80	53	42.5
3:00	75	51.5	80	53	42.5
4:00	80	52.5	80	53	42.5
5:00	85	52.5	80	53.5	42.7
6:00	90	54	80	53.8	43
6:15	93	54.2	80	54	43.1
Following Day					
4:00 P. M.	90	56.5	80	53.3	43

With a 20° F. brine tank temperature, the circulating air passing through the cold-air flue is at least 10° F. warmer than the brine-tank temperature, as only part of this air actually comes in contact with the 20° F. brine-tank surface.

If we then assume that the air is saturated with moisture at a temperature of 10° F. warmer than the surface of the cooling unit, this value will closely approximate the actual condition in service. Then knowing the higher temperature at any part of the food compartment, the relative humidity can easily be obtained from the humidity tables.

The warmer air having a greater water vapor capacity therefore, the per cent relative humidity gradually decreases as the circulting air passes up through the food compartment.

Desirable Humidity Indoors.—Humidity control in homes is becoming more and more important, especially in localities where the outdoor temperature in winter drops to below freez-

ing. The average relative humidity in heated rooms ranges from 10 to 20 per cent in winter. This is a dryness greater than that of the deserts. The relative humidity should not be below 40 per cent for good conditions in regard to health and comfort. The usual practice in buildings where the humidity is controlled is to regulate the relative humidity to between 40 and 50 per cent.

TABLE LXXVI.—WEIGHT PER CUBIC FOOT OF AIR, WATER AND SATURATED MIXTURES OF AIR AND WATER VAPOR AT DIFFERENT TEMPERATURES AND UNDER ORDINARY ATMOSPHERIC PRESSURE OF 29.921 INCHES OF MERCURY.

Temp. Deg. F.	Weight of the Air in Pounds	Weight of the Vapor in Pounds	Weight of Mixture in Pounds
0	0.0863	0.00079	0.08709
12	0.0840	0.000130	0.084130
22	0.0821	0.000202	0.082302
32	0.0802	0.000304	0.080504
42	0.0784	0.000440	0.078840
52	0.0766	0.000627	0.077227
60	0.0751	0.000830	0.075930
62	0.0747	0.000881	0.075581
70	0.0731	0.001153	0.074253
72	0.0727	0.001221	0.073921
82	0.0706	0.001667	0.072267
92	0.0684	0.002250	0.070650
100	0.0664	0.002848	0.069248
102	0.0659	0.002997	0.068897
112	0.0631	0.003946	0.067046
122	0.0599	0.005142	0.065042
132	0.0564	0.006639	0.063039
142	0.0524	0.008473	0.060873
152	0.0477	0.010716	0.058416
162	0.0423	0.013415	0.055715
172	0.0360	0.016682	0.052682
182	0.0288	0.020536	0.049336
192	0.0205	0.025142	0.045642
202	0.0109	0.030545	0.041445
212	0.0000	0.036820	0.036820

Table LXXVI gives the weight per cubic foot of air, water and saturated mixture of air and water vapor at different temperatures, and under the normal atmospheric pressure of 29.921 inches of mercury for tempertures ranging from 0° F. to 212° F. The second column shows how the weight of the dry air in the mixture decreases when the temperature increases. The last column shows how the total weight of the mixture in pounds decreases with the increase in temperature.

The relation of the air temperature and the difference between the wet and dry bulb thermometer readings, as affecting the relative humidity of air, is shown by Fig. 208. The various curves in this figure, labed 20, 30, 40, 50, 60, 70, 80, and 90, are relative humidity curves of air in per cent of the saturated condition at 30 inches of mercury as the atmospheric pressure. The data shown on this figure were taken from reports of the United States Weather Bureau. The air temperature which is plotted on the left-hand side of the diagram corresponds directly to the temperature of the dry-bulb thermometer. The figure shows graphically how the relative humidity increases with the relative increase of the dry-bulb temperature and the relative increase of the difference between the wet and dry-bulb thermometer readings.

Placing of Food and Ice in Refrigerators.—The National Association of Ice Industries has recently published bulletins in reference to the operation of household refrigerators, in which attention is given to "Where to Place Food in Household Refrigerators" and "How to Use Ice." These bulletins have been extracted as follows:

WHERE TO PLACE FOOD IN THE HOUSEHOLD REFRIGERATOR

The home refrigerator is really the food warehouse of the family, just as the great, clean cold warehouses in the big cities are the refrigerators of the people of the cities, to keep food clean, sound, and wholesome, between the time the refrigerator car brings it from the country and the time that the people are ready to eat it. Just as the house manager must keep some food supplies for the near future, so must the food distributing industry in the cities keep a food supply ahead of food consumption. One is just a magnification of the other.

The big warehouses have great rooms where low temperatures which do not vary the year around, are adapted to the kinds of food to be kept. For instance, eggs are kept at 29° to 31° F., while butter is frozen hard and kept about 5° below zero. All the rooms are very clean.

Just so should we plan for the home refrigerator. The refrigerator should be spic and span. Everything that goes into it should be as clean as possible. This will help in two ways: First by keeping out bacteria, and second, by making the cleaning of the refrigerator a much more simple matter.

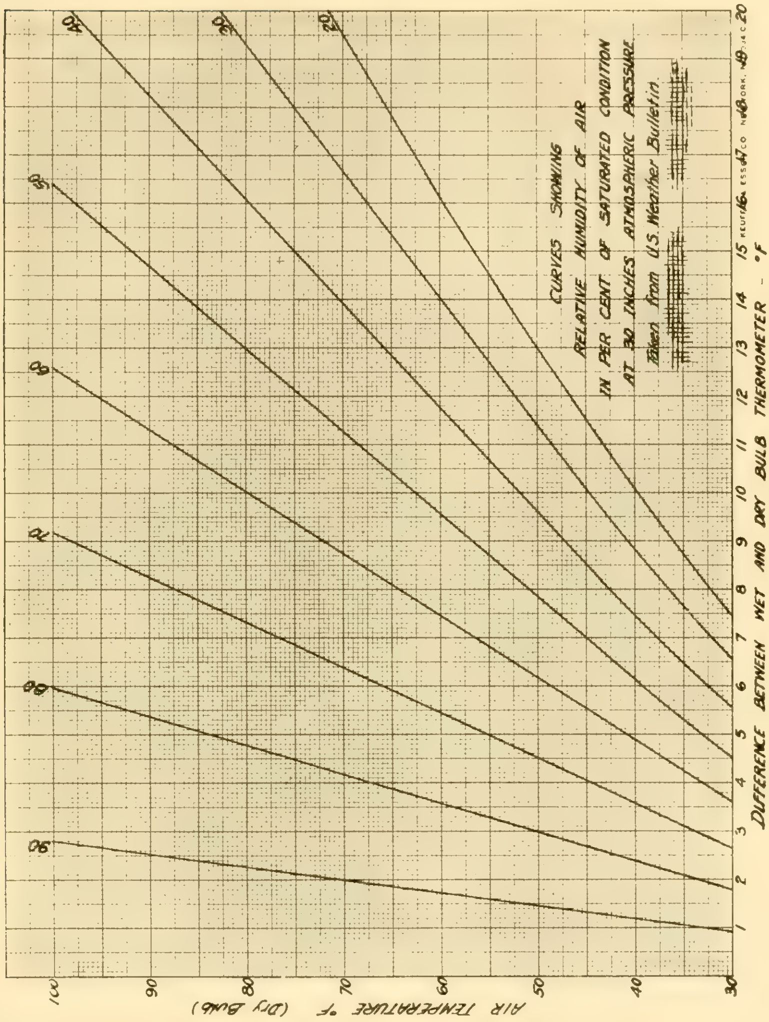


FIG. 208.—RELATIVE HUMIDITY CURVES.

Foods requiring the lowest temperatures obtainable should be placed in the coldest part of the food chamber, while those commodities which do not demand such care may be placed in less cold locations.

Let us consider the placing of food in the refrigerator on this basis. First, look critically at the construction of your refrigerator. Is it an "over-head" or a "top-icer" type? In an "over-head" icer type, the coldest place is in the middle of the top shelf where the cold air drops down from the ice chamber, and the warmest place is on the sides of the lower shelves where the warmed air travels back to the ice chamber. In a refrigerator of the "side-icer" type, the coldest part is in the compartment directly under the ice chamber.

Keep Air Ducts Open.—When food is placed in the household refrigerator, be careful not to shut off the exit of cold air from the ice and the entrance of warm air into the ice chamber. There must be circulation in order to insure a steady supply of clean, dry, cold air. For this reason, leave enough room between containers on the shelves to enable the air to flow freely.

How to Use the "Side-Icer."—Foods that are delicate and absorb odors should be placed directly under the ice chamber where they will be coldest and get fresh, clean cold air. Milk, butter, meat broths, and moist cooked foods such as cereals, custards, and cream sauces come under this head.

Of all the perishable foods going into the refrigerator, milk needs the most intelligent care. It is an ideal medium for bacterial growth at favorable temperatures. Because milk is a food depended upon by young children and invalids, the decomposition of products produced by bacteria should be especially guarded against. Fortunately low temperatures are excellent deterrents to bacterial multiplication and unless the milk freezes—which does not happen until below 28° F., they do not alter it either chemically or physically. Therefore, place the milk in the coldest part of the refrigerator which, as stated before, is just below the cold air down drop. Milk bottles may take some dirt into this most important compartment of the refrigerator. They should be washed, but care must be taken that the cap is not soaked nor water permitted to remain on the cap because if it gets wet, bacteria can easily enter the bottle.

Next to milk, meat broths are probably the most delicate foods to be cared for. They should be placed, while hot, in sterilized containers, covered tightly, and allowed to cool to room temperature, then placed in as cold a location as your refrigerator affords. In fact, all these delicate foods should be placed in sterilized covered containers.

Butter should be placed here for two reasons. First, the temperature tends to hold back rancidity; second, butter absorbs odors

and flavors very readily. Therefore, give it a tight container or hold it in the original package.

Drinking Water.—During warm weather some people want drinking water cold but not iced. Choose clean containers such as quart fruit jars, fill them with water and place them just below the ice chamber. Sometimes spring water is purchased or the water supply must be boiled to make it fit for human consumption. If water must be boiled do so, then put it into sterilized containers, let it cool to room temperature and place the covered jars in the refrigerator just under the ice chamber. This gives a supply of well cooled water.

Desserts.—Jellies, charlottes, and heavy cream desserts go in the coldest compartment until they are set, then if space is scarce they may be transferred to the meat compartment.

Meats.—Uncooked meats should have the next coldest place. Always remove the paper wrapper from the meat when it comes from the market. Paper left on meat sticks, and becomes very difficult to remove, and a slime may develop. Place the meat on a clean dish and put it on the bottom of the food compartment. Cooked meats dry out very quickly, so if you wish to keep them in the best condition, put them in tightly covered containers. Space is valuable in this compartment, so use containers that are relatively high and narrow. Use as few plates as possible. While large pieces of meat, such as roasts and poultry, must be put on plates, many meats such as steaks, chops and meat for stews, may be placed in tall containers that require less room. This applies in general to all parts of the refrigerator. If containers that are as tall as will fit well on the shelves are used, the space in the refrigerator will be utilized to much better advantage.

Fish.—Fish may be kept in the refrigerator safely if it is placed in a tightly covered vessel. The purchase of a white enameled container for this purpose will be a wise one because fish should be a frequent food in the home.

Left-overs.—The question of left-overs is a very important one. They should be placed in the coldest location space permits if they contain cream sauces or custards, or are some delicate vegetable such as asparagus. All others should go in the meat compartment or directly over it. In any case, do not place the left-overs in the refrigerator in the dishes in which they were served at the table. It is hard on the china and also takes up more room than is necessary. Try putting left-overs in the various jars that accumulate in the household from the purchase of mayonnaise and other products, adapting the size of the jar to the quantity to be salvaged. Save these small portions, mix them with originality and imagination, two of the finest

ingredients in the food catalog, and utilize them as attractive dishes for lunch or supper or even another dinner.

Berries and Cherries.—On the shelf above the meat compartment place berries and cherries. They are especially subject to a white mold which causes quick decay. Dry cold air checks the growth of this mold. Do not wash the berries until ready to use them. Put them in a well-ventilated container, such as a wire sieve with the handle removed, or in the original wooden box if clean and dry, but remember not to crowd the berries, for they will resist mold longer if the dry air can circulate freely around them.

Eggs.—On the same shelf place eggs and such fruits and vegetables as do not have a decided odor or flavor. Contrary to the general opinion, eggs do not need the coldest place in the refrigerator. It they are placed on the middle shelf of the food compartment they will keep well.

Vegetables and Fruit.—Try washing lettuce and celery when it comes from the market. Shake it free of water, and then put it in a tightly covered jar. It will keep fresh and crisp for days and does not get broken so readily as when stored in a towel or paper. It also makes a neater appearance in the refrigerator. Try, also, keeping new carrots, fresh peas, string beans, and other succulent vegetables cold until needed for use. Set the bunch of asparagus in a shallow pan of water and give it refrigerator room.

Place all foods with strong odors high up in the food compartment where the air current strikes them just before it returns to the ice chamber. Then the odors will be absorbed by the film of water on the melting ice and pass off with the meltage. Foods such as melons, oranges, peppers, cabbages and apples are on this list. They all dry out readily so do not remove the oiled or tissue paper wrapper that comes on the fruit.

How to Use the "Over-head" Icer.—When the ice in the refrigerator is above the food compartment, the cold air outlet may be a long narrow opening at the back of the ice chamber, or there may be an opening in the middle of this floor through which the cold air is discharged. Generally the warmed air rises along the side walls and passes through ducts or flues into the ice chamber. The path which the air takes shows us where to place the various foods depending upon their susceptibility to the effect of temperature.

Of course the coldest place is just under the cold air drop and the warmest is usually at the extreme edge of the bottom shelf. The top shelf in this type of construction just reverses the "side-icer" rule and is our low temperature location. Each succeeding shelf shows a slight increase in temperature, but, ordinarily, the extremes of high

and low are not so far apart as when ice is placed in the upper side quarter.

With these fundamentals clearly in mind, we readily see that milk, butter and broths and other very delicate products should have the middle portion of the top shelf; meats, fish and the delicate desserts should occupy the middle of the shelf just below, while fresh vegetables and rather resistant foods should be placed on the floor of the refrigerator. Foods with pronounced odors such as cabbage, oranges and apples should be placed near the side walls where the air currents are traveling quickly to the ice chamber. There they discharge their load of heat and odors and the moisture which the expanding air gathers from the food.

Don't forget that the well constructed refrigerator, well filled with ice, maintains an active circulation and so causes some evaporation of moisture. Therefore, heed the advice about keeping the tissue paper wrapping on such fruits as oranges and apples.

Remember too, that the wrapped orange has never been touched by human hands. Good fruit handling demands gloves on all pickers and graders. Just think! Forty-seven per cent of our people are engaged, in one way and another, in the feeding of us all. It is one of the wonders of the modern world—this production and distribution of foods. The home refrigerator is the last link in the long chain necessary for the proper distribution of food.

HOW TO USE ICE.

We are all interested in knowing about the proper use of ice—how to get the most benefits from its use—how to make sure of food and health protection, but how much thought, frankly, have you ever given to the importance of using ice the year round? If yours is the average family, you have given it little thought indeed, because the average family lets the weather decide its use of ice.

The people in the business know that the high-climbing thermometer will always be the greatest ice salesman, but we also know that more and more thoughtful people are using ice every month and day in the year.

Ice is the only certain, sure, positive protector of food's purity—no matter whether the day be New Year's or the Fourth of July. Doctors will tell you this. Domestic science authorities confirm the fact. No cellar, window box or back porch can keep and protect the foods which cost so much more than the few cents of ice needed to keep them properly.

You are taking chances when you try to keep food outside of a well-iced refrigerator. You are exposing it to all manner of dangerous, sickness-breeding bacteria. You are exposing it to dust, grime

and the unevenness of temperatures that never gives real food preservation.

How to Keep Food Properly.—A refrigerator furnishes an even, bacteria-destroying low temperature. The housewife who tries to keep food in any other way is continually risking the family health. Bacteria multiply in all foods when the temperature is above a safe point. Most authorities agree that the dividing line between danger and safety in food temperatures is 50 degrees. Only in a refrigerator will you find the low temperature that precludes danger of contamination, spoilage and germs.

How to Gain Real Economy.—While many housewives grant the fact that food can be kept properly in refrigerators—and in that way alone—they fail to keep their food properly by taking less ice than they need. They let the ice chamber get so low that it is frequently less than half full. Then the refrigerator cannot do its part; it takes ice and plenty of it to obtain proper refrigeration. Also, from the pocketbook standpoint, ice melts rapidly when the supply gets low—more rapidly than when you keep the ice chamber comfortably filled. If you let your refrigerator get warm, it takes much more ice to chill it again than it would to keep it cold. Ice is an article you cannot economize on by skimping.

Simple Rules for Preventing Waste.—Keep the ice chamber of your refrigerator well filled. The ice melts more slowly.

Have the refrigerator large enough. Do not crowd it full of food. It is not the size of the box so much as the quality of food which consumes the ice.

Keep the refrigerator in a cool spot, away from draft.

Close the doors tightly to prevent warm air from seeping in. Open the doors as little as possible.

Don't put any food on the ice or in the ice chamber; leave the ice uncovered.

You may have been told that wrapping your ice in newspapers, cloths or blankets, tends to keep it from melting. This practice is bad, because it prevents the free circulation of air around the ice, and that in turn prevents the purification of the air. The whole surface of the ice is needed to purify the air properly.

Never put hot food in the refrigerator. Let it cool a bit first.

It is a great mistake to have too small a refrigerator for the amount of food in it. There is not room for enough ice. The food is a heating element, and melts the ice faster than the ice can chill the food. Too much crowding of food also obstructs the air circulation so essential to keeping the flavor fresh and appetizing.

Placing the Refrigerator.—Your refrigerator may look stout and tough, but in reality, great care must be taken to see that it is properly placed. Few people realize the importance of this.

Place the refrigerator where it won't overheat or be exposed to moisture, draft or sudden changes of weather.

A porch, even though protected, and a cellar are bad places for it. The best place is in the kitchen near the rear entrance. This may not be as convenient as a little nearer the working section; but it saves the iceman crossing your kitchen. The ideal arrangement, of course, is an outside icer opening on the porch.

Opening and Closing Refrigerator Doors.—One of the quickest ways of spoiling the efficiency of your refrigerator as a preserver of food is to open the doors too often and keep them open too long. Tests have shown that in opening the door the temperature inside rises at least two degrees.

Some housewives open the box every time they want a single article of food, instead of taking out several articles at once which may be needed about the same time.

Refrigerator doors should be kept tightly closed. When not quite shut they leave a crack between the door and its frame and warm air seeps in or the cold air pours out. Under such conditions, it is impossible to keep the inside cold. It is also bad for the doors. The meeting of warm air on one side and cold on the other develops moisture and that makes the door warp and swell. This "sweating" is especially noticeable on warm, damp days.

Keeping the Refrigerator Clean.—It is very important to keep your refrigerator spotlessly clean. That is literally true. A single drop of spilled milk or of other food can contaminate a refrigerator in a few days. One drop of milk can develop millions of bacteria if the temperature is right for it.

In cleaning a refrigerator use a sponge or soft cloth and clean water. Don't use any sponge or cloth and any water. You do not have to give your refrigerator a weekly hot scald. You can clean it thoroughly with lukewarm or cold water and washing soda, followed by a rinse with clear cold water and then a thorough drying. Hot water heats the wall unnecessarily. Be sure to leave them perfectly dry. Moisture is bad.

A friction powder or steel wool may be used on the ice compartment and drain only. The drain is the most difficult part to clean; use a long handled brush with steel wool packed into it.

To be thoroughly clean a refrigerator should have no cracks or crevices in which dirt or germs can lodge. It is almost impossible to clean them out. In purchasing a new refrigerator, be sure to get one that may be easily and thoroughly cleaned.

CHAPTER XI.

TESTING OF ICE REFRIGERATORS.

Constant Temperature Room.—A constant temperature room is necessary to accurately test the heat leakage of a refrigerator. Electrical thermostats and heaters are of considerable value for tests of this kind. It is easily possible to maintain a room temperature which will vary not more than 1° F.

Fig. 209 shows an arrangement which has proven very satisfactory for a constant temperature room. The electrical heaters are screened so that radiant heat will not pass directly from the heaters to the outside surface of the refrigerator being tested. It is always difficult to measure radiant heat. With high room temperature, the heaters must be on a greater percentage of the time, therefore the heat exchange by radiation would increase greatly unless the heaters are screened. An asbestos curtain is used for this purpose. There is a circulation of air as indicated by the arrows, insuring a uniform temperature in different parts of the constant temperature room.

Fig. 210 shows another arrangement for a constant temperature room using a double wall. The heaters are placed between the walls and the warm air circulates under the floor, over the ceiling and along the walls. This method reduces variation in radiation and convection, due to using the heaters in order to operate at a high room temperature.

In order to obtain accurate results, it is best to use as little electrical heat as possible and yet keep the temperature of the test room constant. In this way the heat losses due

to radiation and abnormal convections are reduced to a minimum.

It is also desirable to control the humidity of the constant temperature room. This factor is not as important on a heat insulation test as with an ice melting test.

Ice Melting Method.—A simple method of measuring the heat leakage is by the ice melting method. The refrigerator

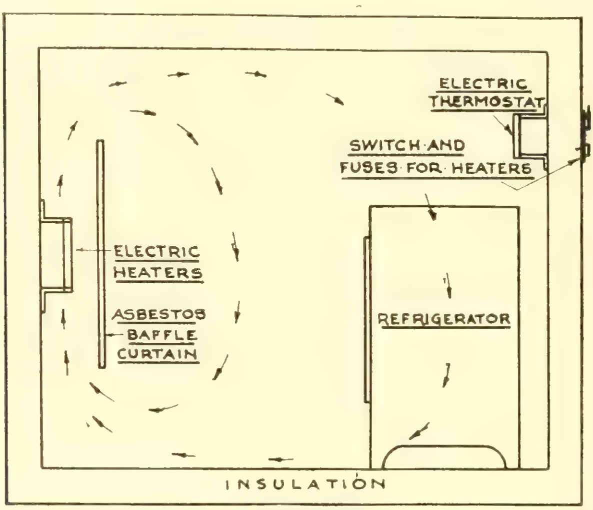


FIG. 209. CONSTANT TEMPERATURE TESTING ROOMS.

must be in use at least 24 hours in order to have the lining and insulation cooled to about the same temperature as they will be during the test. The author has found that a cabinet insulated with three inches of corkboard required three days to establish a temperature equilibrium in the walls.

A weighed block of ice is then placed in the ice compartment, noting the shape of the block so that on a subsequent test a similar shape can be used. Then after a certain period, say 24 to 48 hours, the ice block is weighed again to detect the amount of ice melted. Suppose the pounds of ice melted per 24 hours to be W. Then the heat leakage for the cabinet H

would be $144 \times W$ in B.t.u. per 24 hours. The heat leakage h, per sq. ft. per degree F. per day would be:

$$\frac{144 \times W}{\text{Sq. ft. mean area} \times (\text{room temp.} - \text{average cabinet temp.})}$$

Temperatures should be taken of the coldest and warmest part of the food compartment. It is very important to have

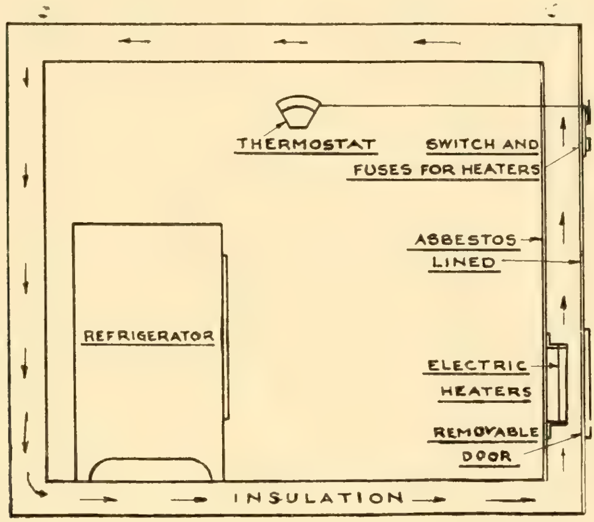


FIG. 210.—CONSTANT TEMPERATURE TESTING ROOMS.

a certain amount of dishes and food on the shelves in making a test if the actual service conditions are desired. Service conditions can be closely duplicated by having plates of potatoes in 10 or 20-pound units. Two or three times a day a certain number of cold units are removed from the cabinet and the same number of warm units (at room temp.) are used to replace them.

Some of the more important variable factors entering into a heat leakage test by ice melting are as follows:

1. Constantly changing weight, surface and form of ice cake.
2. Circulation is affected by size and position of ice cake.
3. The water from the melting ice may assist in cooling cabinet.

The instruments required for a test are thermometers, preferably of the recording type. If regular glass stem mercury thermometers are used, it is advisable to place them in a small flask filled with oil. The flask should have a cork with the thermometer held in place in a small hole through the cork. This eliminates the error of reading a rapidly rising temperature when the door of the cabinet is opened.

Electrical Heater Method.—The electrical heater has advantages over the ice-melting method of testing the heat leakage of a refrigerator cabinet. The circulation is not changed by a different shape of the ice cake, and the rate of heat supply may be kept quite uniform and may be measured accurately even without opening the doors of the cabinet under test.

Suppose an ice test indicates that a cabinet would be used with an average food compartment temperature of 45° F. in a 75° F. room. The temperature differential through the wall is therefore 30° F. To conduct a heat test, say in an 80° F. constant temperature room, a heating element is placed in the cabinet so that it will have the same wall differential temperature of 30° F. Therefore, the food compartment temperature is maintained at 80° F. plus 30° F. or 110° F.

If the electrical heating element requires 20 watts in order to maintain this 30° F. temperature difference through the walls of the cabinet, then the total heat leakage in B.t.u. per 24 hours $=20\times24\times3.416=1640$. (1 watt hour of electrical energy is equivalent to 3.416 B.t.u.)

The heat leakage is usually rated by the number of B.t.u. lost per square foot per degree temperature difference per day. Suppose the average surface of the inside and outside walls to be 20 sq. ft., then

$$\frac{1640}{30\times20}=2.73 \text{ B.t.u. heat leakage per sq. ft. per degree F. per 24 hours.}$$

Sources of Heat Losses in Refrigerators.—The following pertains to a test on an ice refrigerator to determine rate of ice melting due to heat loss of insulation, opening doors, and changing food.

The object of this test was to determine the relative amount of ice melted by the three principal heat losses which occur in an average household refrigerator. These are:

1. Heat transfer through the insulated walls.
2. Opening doors allowing warm air to enter, and cold air to drop out of the refrigerator.
3. Changing food or placing in the refrigerator, food and dishes to be cooled.

The refrigerator was a top icer with panel construction throughout and had the following specifications:

	Inches Height	Inches Depth	Inches Width
Outside Compartment	60	21	29
Food Compartment	28	15¾	22½
Ice Compartment	16½	16½	20½
Food Compartment Door Opening	26	..	20½
Ice Compartment Door Opening	14	..	20½
Volume Food Compartment	5.7 cubic feet		
Volume Ice Compartment	3.2 cubic feet		
Total Inside Surface	28.9 square feet		
Total Outside Surface	40.0 square feet		

The insulation consisted of the following:

1. Oak case.
2. ½-inch mineral wool.
3. 2 air spaces.
4. Layers insulating paper.
5. ⅜-inch spruce wall.
6. Porcelain on steel lining.

The rated ice capacity of the refrigerator was 120 pounds and the net weight of the refrigerator was 280 pounds. The flue opening was 1⅛ inches wide on both sides of the ice compartment and extended the total depth of the compartment. There was a 2-inch air space under the ice shelf.

The test was conducted in a constant temperature room. The room had double walls on all six sides. The effect of heat transfer by radiation from the electric heaters used to maintain a constant temperature was eliminated by placing the heaters between the double walls of the room. The operation of these heaters was controlled by a thermostat. The humidity of the room was controlled by an electric humidostat.

It was found necessary to maintain constant condition of temperature and humidity for several days before an accurate

reading could be obtained of the amount of ice melted for each particular test condition.

Throughout the entire test, the room temperature was maintained at 75° F., while the relative humidity was maintained at 40 per cent. The quantity of ice, as well as the ice surface exposed, was kept as nearly uniform as possible throughout the test.

The refrigerator was first operated without any food changes or door opening process. The food compartment was empty so that the heat losses were due entirely to the heat transfer through the insulation of the cabinet. Of course, a very small percentage of this heat loss was caused by cooling and dehumidifying warm air which leaked into the cabinet, replacing cold drier air which leaked out, and a small loss due to heat transfer by radiation which could not easily be measured.

The food change test was then conducted, the food which, in this case, was potatoes, being changed three times each day. The potatoes were removed at the temperature of the food compartment, while the potatoes placed in the box at each change were at room temperature. The food change consisted of removing a china plate weighing 2.4 pounds holding 8.6 pounds of potatoes, and then placing a similar quantity of plate and potatoes in the food compartment.

Finally, a door opening test was conducted in conjunction with the food changing test. This approximated the average household service condition, indicating the difference between a laboratory test and actual household service conditions.

During this test, the relative humidity of the room was maintained at 40 per cent, while the relative humidity in the lower part of the food compartment of the refrigerator varied from 62 to 68 per cent.

The results of the ice-making tests indicated that 93 per cent of the ice was melted, due to heat transmitted through the insulation, 4 per cent was required for cooling the food at the rate of 33 pounds per day, and that 3 per cent was lost in the opening of the doors which occupied one minute per hour, or a total of ten minutes during the test. These losses are shown graphically by Fig. 211. The foregoing data, to-

gether with Fig. 211, illustrate the great importance of having a refrigerator efficiently insulated.

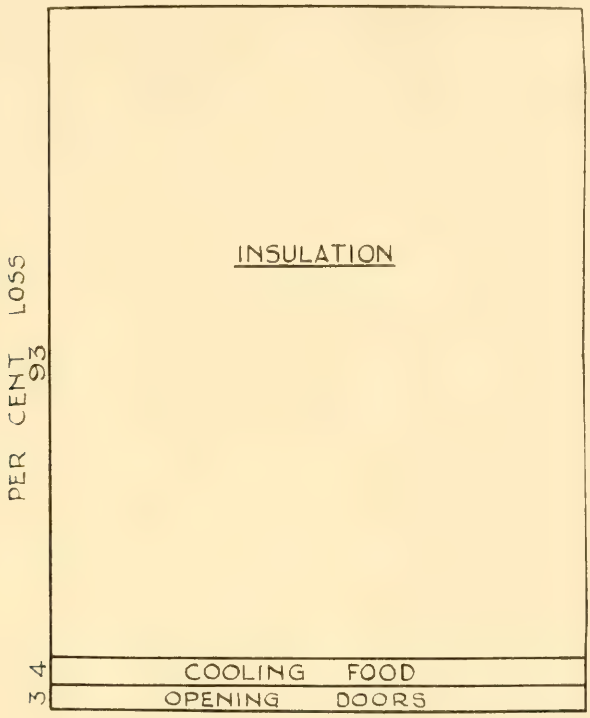


FIG. 211.—COMPARISON OF REFRIGERATOR HEAT LOSSES.

Effect of Room Humidity.—The following test was on an ice refrigerator to determine the effect of room humidity on the rate of ice melting. The refrigerator used in this experiment was the top icer described in the previous report. The test was conducted in a constant temperature room in which the humidity could be regulated and controlled very closely. The room temperature was maintained at 75° F. during the entire test which lasted 22 days.

During this test the food storage space in the refrigerator contained only a recording thermometer and a recording humidostat. The quantity of ice as well as the amount of ice surface was maintained as nearly constant as possible. The

following results were obtained with two different conditions of room humidity:

Room Temperature Degrees F.	Per cent Relative Humidity		Ice melted per day, pounds
	Food Compartment	Room	
75	65	40	17.75
75	65	75	22.56

This test shows that the rate of ice melting was increased about 27 per cent, simply by changing the relative humidity of a 75 degree room from 40 to 75 per cent. This difference would be greater in actual service conditions as the doors are opened more frequently and sometimes not closed tightly, thus greatly increasing the amount of air leakage.

It is therefore very important in refrigerator tests to know the relative humidity both of the air inside the refrigerator and of the room in which the refrigerator is located.

Room or refrigerator environment air is constantly leaking into the upper part of a refrigerator, replacing the cold air leaking out of the lower part. This warm air circulates and is cooled to the food compartment temperature by coming in close contact with the ice or cooling element. Heat must be absorbed, either by melting ice or evaporating the liquid refrigerant, to counteract the following heat losses:

Heat losses due to air leakage or refrigerator ventilation.

1. To cool incoming dry air.
2. To cool moisture of incoming air.
3. To condense part of moisture of incoming air.
4. To freeze the condensed moisture. In a mechanical refrigerator the surface temperature of the cooling element is usually below 32° F.
5. To cool the frozen moisture.

It is then readily understood that with a nearly constant supply of warm room air entering the refrigerator, it will require more heat to cool and dehumidify to the same dryness the 75 per cent humidity air than it would to cool and dehumidify the 40 per cent humidity air.

Humidity Diagram for Room and Refrigerator.—Fig. 212 shows the relation between room and food compartment humidities. This test was made in a constant temperature room held at 86° F.

The mechanical refrigerator maintained a temperature of 42° F. in the lower and 50° F. at the top of the food compart-

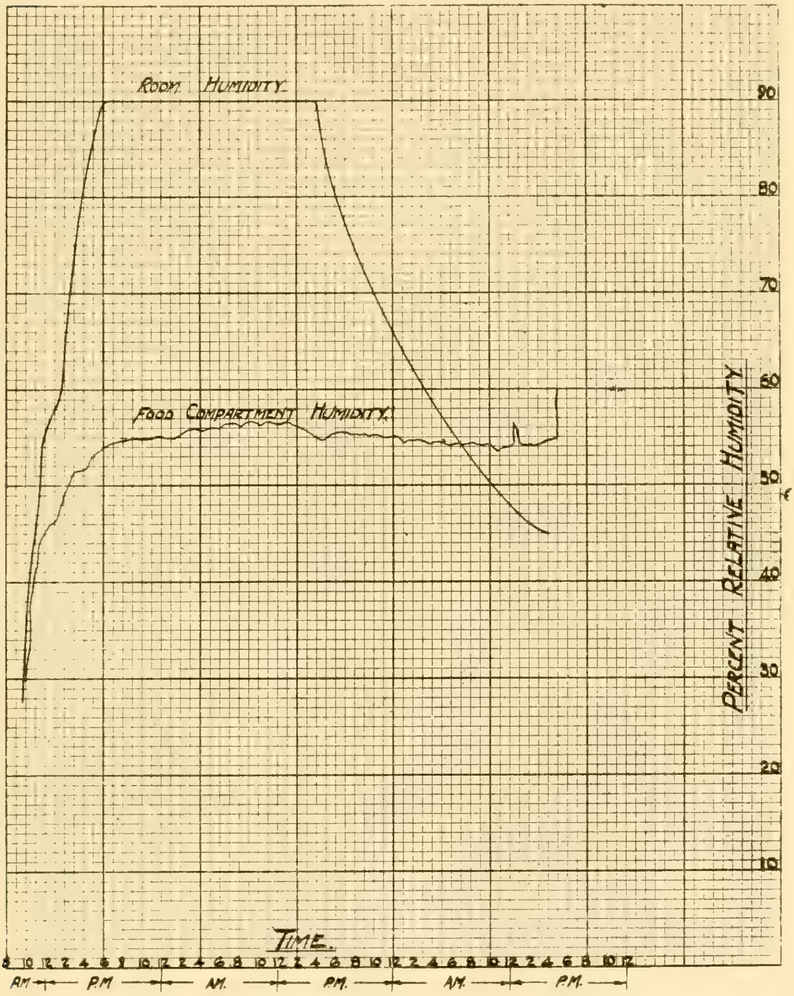


FIG. 212.—RELATIVE HUMIDITY IN REFRIGERATOR.

ment. The refrigerator contained only the recording instruments. The average brine tank temperature was 20° F.

The test was started with a warm refrigerator so that the temperature and humidity of both room and food compartment were equalized.

Calorimeter Testing.—There is a great difference of opinion as to the proper method of determining the exact or comparative rating of household and small commercial compressor units.

From tests compiled by various manufacturers of household machines, the simplest and by far the most practical for every day usage, was found to be actual measurement by volume of the refrigerant circulated, usually in a calibrated drum with sight glass, located directly under the condenser. By using the pressure on this drum at the beginning and end of the test, the mean pressure is obtained for determining the exact density of the liquid from authoritive tables on refrigerants.

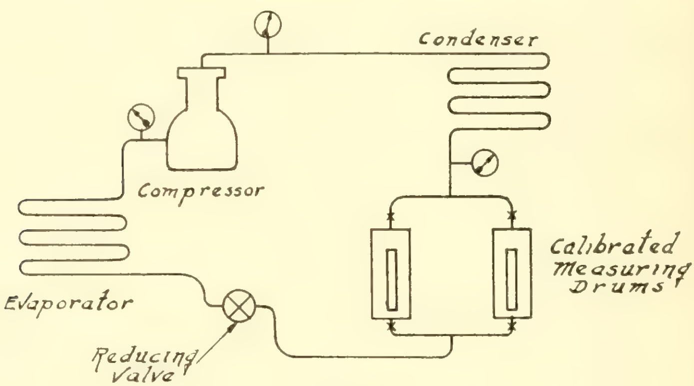


FIG. 213.

After the actual pounds of refrigerant circulated has been found, the net available B.t.u. per pound of refrigerant can be determined from the table. This value multiplied by the pounds circulated gives the total B.t.u. of refrigerating work done in the evaporator.

As numerous tests have demonstrated, superheating of the suction gas to the compressor has very little effect on compressor capacity under normal operating conditions, so that the volume of gas per pound of liquid can be obtained from the refrigerant table for the suction pressure noted near the compressor. This volume per pound multiplied by the pounds circulated will give the volume of gas handled by the compressor.

If the volume of gas handled by the compressor is divided by the piston displacement of the compressor for the same interval of time, the actual efficiency of the compressor is obtained. It has been found that the error between this determination method and the use of a calorimeter or B.t.u. measurement box around the evaporator is practically negligible, and is much simpler.

As a general rule, the determination which is most desired by all users of refrigeration is how much power must be paid for at the end of each month for holding the refrigerator at a temperature which best conserves food. The problem then becomes, how many kilowatts or their equivalent B.t.u.s must be paid for in power consumption for a definite number of B.t.u.s actually abstracted from the refrigerator?

If a unit B.t.u. per hour abstraction is used as a basis, the machine requiring the minimum B.t.u. input for this work would be the most efficient overall, which, in the end, is the determining factor, provided the machines rate equal mechanically in construction. This value has been given the name "Performance Factor" and from the consumer's viewpoint is the most important, if other considerations such as appearance, size, arrangement, ice cubes, etc., are basically equal. A unit of comparison sometimes used is B.t.u. per Watt hour.

From the manufacturer's standpoint, however, the problem is somewhat different, as it is the individual parts and their efficiencies which affect him, so that each piece of equipment, compressor, evaporator, condenser or motor must be brought up to its maximum efficiency, which in turn will automatically take care of the overall efficiency or "Performance Factor."

Looking at it from this angle the testing must include such factors as discharge pressure, compressor r.p.m. and size, size and type evaporator, size condenser and quantity of air to be blown over it, type drive, type motor and size, arrangement of parts, noise, vibration, lubrication, control, type suction and discharge valves, kind of refrigerant, etc.

Tests are subject to a great many variations which cause duplication of determined data to often be a difficult problem. In tests on a refrigerator load some of the variables that occur

would be: door leakage, air circulation, insulation efficiency, cooling chamber shape and size, location of cooling unit with its shape, size and arrangement, and the important factor of frost accumulation.

As one or more of these variables are always present, test results are subject to numerous interpretations, consequently the least possible number of variation factors that can be included in a test, the more correct will be the analyzed results.

If comparative tests are to be run, the factors entering into the results need only be considered and held the same for all tests and the resultant values will give a true comparison.

When running a comparative test on various makes of equipment and boxes, it is assumed that each manufacturer has made each part of his apparatus as efficient as he knows how, commensurate with cost, consequently the "Performance Factor" test appears to be the most logical and at the same time, the most acceptable method of true accomplishment.

A comparative method for determining compressor efficiency and at the same time, a very simple one, is the so called "Pump up" test. By using the same receiver on the discharge side of the compressor, and finding the interval of time necessary to pump a pressure of, say, 75 pounds on the receiver, a quick and comparatively accurate comparison is obtained on compressors of the same bore, stroke and r.p.m.

This method can be carried somewhat further and by reducing the volume of 75 pounds compressed air to 0 pounds or atmospheric intake pressure, assuming the temperature to remain the same, the volumetric efficiency of the compressor can be found by dividing this volume by the actual piston displacement for the "Pump up" time interval.

Another method for obtaining approximate compressor efficiencies, is by means of metering the discharge of air through an air meter for atmospheric intake and varying discharge pressures, using compression ratios for conversion into an equivalent amount of refrigerant gas.

A suggestion for standard conditions of testing for all makes of household refrigerating equipment would be the

power consumption of the motor, where an average temperature of 45° is maintained in the food compartment with 80° average outside air temperature. Another test should be made with an average outside temperature of 100°.

Earlier Research on Refrigeration in the Home.—Research on refrigeration in the home was carried out by John R. Williams, M. D., to obtain data in order to present a paper before the Third International Congress of Refrigeration, on the subject of "A Study of Refrigeration in the Home and the Efficiency of Household Refrigerators."

Dr. Williams has obtained some interesting information in reference to the construction of household refrigerators in actual use, the temperatures prevailing in the rooms and in the refrigerators, the relative amounts of ice used, etc. Dr. Williams' paper was as follows:

A STUDY OF REFRIGERATION IN THE HOME, AND THE EFFICIENCY OF HOUSEHOLD REFRIGERATORS.

The problem of preserving fresh food from decomposition is one which every household is called upon to solve. The cheapest, most efficient, and most available agency for this purpose is refrigeration or storage at low temperature. In the home the pantry, cellar or an ice-box is depended upon to furnish the low temperature required for proper food preservation.

There is scientific as well as practical basis for this use of cold. It has been demonstrated by laboratory experts that bacteria, which are the cause of food decomposition, are markedly retarded in their growth by temperature below 45° F., and that temperatures between 45° and 50° inhibit to a slightly less extent the propagation of these organisms. Above 50° F. bacteria multiply prolifically. This means that foods favorable for the growth of bacteria, as milk, meat, etc., undergo very slight decomposition when kept at temperatures ranging below 50° F., but above that temperature they spoil very rapidly It follows, therefore that a box or room for the storage of perishable foods, to be at all efficient, must have a temperature not in excess of 50° F., preferably below 45° F.

Even the most favored cities in the United States, in the matter of climate, have periods of from 5 to 7 months when the temperature averages above 50° F. Thus the northern city of Rochester for more than six months of the year has a mean monthly temperature above 50°, as will be seen by the following tabulation, showing the mean monthly temperature of Rochester, N. Y., from 1872 to 1911, inclusive, for the warm months of the year:

	Degrees F.		Degrees F.
May	56.7	August	68.9
June	66.2	September	62.8
July	70.9	October	50.0

During these warm months, artificial means must or should be employed to protect fresh foods from decomposition. House temperatures, even in the cellar, are rarely much lower than those of the outside air. The mean temperature for the month of August, 1912, was 68.9°., while the average temperature of 266 cellar bottoms was 63° F. The importance of these facts will be better appreciated when it is understood that nearly half of the homes in Rochester rely upon the cellar for the protection of their perishable foods. In an investigation of more than 5,450 homes, it was discovered that 2,450 families do without ice the year round and depend upon the cellar or pantry to afford the proper temperature conditions for food preservation. Yet in the study of cellar temperatures in several hundred homes not one was found having a temperature below 55° F. Pantries and kitchens were observed to be even warmer, for not one of either was found having a temperature below 60° F. The obvious conclusion from this investigation is that every home should have artificial means of refrigeration.

As has just been indicated, about 55 per cent of the homes in Rochester use ice during a part of the year, and most of these homes are provided with some kind of an ice box. The endeavor was made to determine how efficient are these refrigerators, and also to learn with some accuracy to what extent ice is used, its cost, etc. Investigation of the problem was undertaken in various sections of the city, each differing from the others in social or economic conditions. These distinctions are indicated in the accompanying tables. Upwards of 100 homes in each district were studied in the following manner:

A trained investigator, equipped with a set of accurate and delicate thermometers and other measuring devices, visited the homes and made the observations. Cellar temperatures were taken approximately twelve inches from the cellar bottom; refrigerator temperatures were taken in the food chamber. Each temperature observation lasted at least fifteen minutes. In making the test the refrigerator door was opened, the instrument placed inside, and the door closed as quickly as possible. When a box was low in ice, or when conditions were discovered which affected the validity of the test, another observation was made on the following day or the questionable data was rejected.

In this study of ice boxes, a large number were examined and the data from 300 accepted as trustworthy. Of these, only 123 had temperatures below 50° F., the other 177 registered above that temperature and were therefore worthless for preserving food.

The main reason for the inefficiency of these refrigerators is to be found in their defective construction and insulation. Most of them are wooden boxes built of half inch lumber, and are lined with tin, galvanized iron, or zinc. The walls vary in thickness from less than two inches to more than four inches. The space between the metal lining and the wooden sides is supposed to contain some insulating material, as felt, mineral wool, vegetable fibre, or some preparation of cork. In many of them nothing more is to be found than a sheet or two of paper. Since the efficiency of a refrigerator depends in large part on the character and thickness of the insulating material, consideration must be given to these factors.

It has been proven both experimentally and practically that confined air is the best insulator. The property of retarding or resisting the transmission of heat by an insulating agent rests largely in the fact that air is incarcerated within its fibers or cells. The more completely the air is confined, the more efficient is the insulation. An insulating agent, to be of value, must not permit of the circulation of air, nor must it absorb moisture. Moisture and air currents are fatal enemies to good insulation. A refrigerator wall which contains a space large enough to permit of air circulation, will be found defective because the air then carries the heat by convection. Wood, felt, mineral wool, charcoal, sawdust, etc., are fairly efficient when they are dry, but as soon as they absorb moisture, as most of them do, their efficiency markedly declines. When there is inferior or inadequate insulation in the wall of the refrigerator, the heat percolates through, warms the air next to the metal lining and thus favors the condensation of moisture on the metal within the wall. The poorer the insulation, the greater is the precipitation of moisture. This dampness not only serves to corrode the metal lining, but also becomes the medium for the growth of germs and filth. If the insulation has the property of absorbing moisture, as have most of the cheap insulating agents, this water of condensation is soaked up and the efficiency of the insulation is correspondingly lowered. Furthermore, this absorbed moisture serves to warp and rot the wood casing, with the result that doors become ill fitting, permitting warm air to leak into the box, still further lowering the efficiency of the refrigerator, besides uselessly melting the ice. Some manufacturers avoid the corrosion of the metal lining by the use of glass, tile, or vitreous enameled metal. The manufacturers of shoddy boxes are imitating these by coating the cheap metal linings with white paint. Such refrigerators usually have little or no insulation, and are worthless for food protection.

The conditions just described were commonly noted in the examination of refrigerators, particularly in the cheap boxes found in the homes of working people. Many were discovered where the door could not be closed tightly. The effect of these evils is evidenced in

Tables LXXVII and LXXVIII. The average temperature inside of the food chamber in practically all of the cheap boxes was above 50° F., and the lowest temperatures noted, taken usually soon after icing and under the most favorable conditions, were not low enough to be of dependable value. A properly constructed and operated ice box, with reasonable ice consumption, should constantly maintain a difference of at least 25 degrees between the temperature of the food chamber and that of the outside air when the latter is 70° F. or thereabout. As the outside temperature goes down, this difference will diminish. A box which will not maintain an average difference of more than 20 degrees is not much good, and those with even smaller differences.

TABLE LXXVII.—SHOWING TEMPERATURE OF REFRIGERATORS, LIVING ROOMS AND CELLLARS DURING MONTH OF AUGUST, 1912. ROCHESTER, N. Y.

Section	Refrigerators				Living Rooms			Cellars		
	Below 45°	45° to 50°	51° to 60°	Above 60°	Below 60°	60° to 70°	Above 70°	Below 55°	Below 60°	Above 60°
Well-to-do American	29	43	62	4	0	64	61	0	6	78
American laboring	3	17	19	10	0	24	21	0	22	31
Jewish laboring	9	20	47	8	0	28	63	0	0	75
German-American laboring	1	0	49	2	0	4	18	0	4	29
Italian laboring	0	1	6	0	0	0	7	0	0	10
Totals	42	81	153	24	0	120	170	0	32	253

Since the writer undertook to study the problem of home refrigeration, he has been deluged with inquiries as to the best makes of ice boxes and how it can be determined whether or not a given box is a good one. The answer is neither easy nor simple because the problem deals with the combined complexities of economies and the physics of refrigeration. It seems worth while, however, to discuss simply and briefly the technical questions involved.

The amount of money a family can afford to pay for a refrigerator or for proper insulation depends largely upon the cost of ice. If ice can be procured for nothing, then there is little need to pay much to prevent it from wasting. If, however, it is costly, then it will be found economical to pay for good refrigerator construction. The average retail price of ice in Rochester is $8.50 per ton, and this will be used as a basis of calculation in the following discussion. Next in order of importance to the cost of ice, is the cost and efficiency of the insulating agent used in the wall of the box. The purpose of the insulation is to prevent the passage of heat from the outside to

the inside of the box. As said before, the chief value of an insulator depends upon the amount of air entrapped within its cellular structure, and upon its freedom from moisture. If an insulator disintegrates so as to lose its cellular character or air spaces, its efficiency correspondingly declines. If it becomes wet, its value is almost cut in two. In the study of an ideal refrigerator for the home, two factors must be seriously considered, the cost of ice and the cost and efficiency of insulation.

TABLE LXXVIII.—SHOWING THE COMPARATIVE TEMPERATURE OF DIFFERENT MAKES OF REFRIGERATORS IN USE IN ROCHESTER, N. Y., AUGUST, 1912.

Total Boxes Examined	Average Temperature Inside Box, Deg. F.	Average Temperature Outside Box.	Average Difference, Deg. F.	Grade of Box	Insulation.
39	48.4	70.9	22.5	Best	1½-in. mineral wool, 1½-in. flax and paper, 3-in. board.
9	46.3	69.0	22.7	Best	1-in. mineral wool, 3-⅞-in. boards, ½-in. felt.
7	45.5	69.1	23.6	Best	1-in. vegetable fiber, 2-⅞-in. boards, felt sheathing.
6	47.6	69.7	22.1	Best	1½-in. board, ¼-in. vegetable fiber.
7	52.2	69.7	17.5	Medium	
13	51.7	70.4	18.7	Medium	
13	52.7	72.3	19.6	Medium	
11	54.5	73.6	19.1	Medium	Paper, 2-⅞-in. boards.
21	53.7	73 1	19.4	Cheap	Paper, air space, ⅞-in. boards.
6	54.9	70.0	15.1	Cheap	Paper, and board.
8	52.6	73.8	21.2	Cheap	Paper, and board. Air space.
9	52.2	68.9	16.7	Cheap	Paper, air space.
6	57.0	74.4	17.4	Cheap	Paper, air space.
7	56.6	71.5	14.9	Cheap	Paper, air space.
7	50.9	66.5	15.6	Cheap	Home-made boxes, built-in boxes and those unnamed.
22	51 0	71.3	20.3	Mixed	
104	53.3	71.3	18.	Mixed	Miscellaneous boxes, more than 70 different makes.

The average working man who uses a refrigerator spends between $5.00 and $10.00 for the ice he uses during the four or five warm months of the year. See Table LXXIX showing the amount spent for ice by various classes of people. Well-to-do families spend between $15.00 and $40.00 a year for ice. The cost to families in moderate circumstances varies between these extremes.

Refrigerators in the homes of working people cost, at retail, between $10.00 and $20.00. In the homes of those in better circumstances, ice boxes costing from $25.00 to $150.00 are to be found. Most of the low-priced boxes are built more with regard to appear-

ance than efficiency. The majority of them contain practically no insulation. It is not within the province of this paper, nor has the writer the qualifications which would enable him to intelligently discuss the cost of making refrigerators, but it is within the scope of this discussion to consider the economic value to the consumer of improving the quality of the boxes now in use.

TABLE LXXIX.—SHOWING PRICE PAID FOR ICE PER YEAR. DATA FROM 321 FAMILIES.

Section	Under $5.00	$5.00 to $10.00	$10 to $15.00	$15 to $20.00	$20.00 and over
Well-to-do	6	36	33	13	34
American laboring	34	16	5	1	4
Jewish laboring	22	72	10	6	1
German-American laboring	8	14	1	1	0
Italian laboring	4	0	0	0	0
Total	74	138	49	21	39

NOTE: By this table it will be seen that working people spend from less than $5.00 to $10.00 or more for ice in the four or five months of the year in which they use it. Those in better circumstances spend correspondingly more. At least 60 per cent of this money is wasted and lost in the inefficient and uneconomical refrigerators in use. Were this loss applied to the purchase of a good ice box, these families in a short time would have adequate and economical refrigeration, in place of the present wasteful and unsanitary methods.

This point can best be illustrated by considering a specific example. In Table LXXX is shown the relation between the amount of insulation, ice consumption, and cost of operation. The refrigerator is of medium size (42x30x18), of good make, and, as ice boxes go, is well insulated. It retails for about $20.00, more or less, depending upon the trimmings. To be efficient, this box should maintain a fairly constant temperature of 45° F. within the food chamber. To do this, it must maintain an average difference of 20 degrees temperature between the inside and outside of the box. To overcome the heat radiation from a box of this size, and with the kind of insulation within its walls, it would require an ice meltage of approximately 158 pounds per week, or 3,400 for the five warm months. This ice would cost the consumer, at current prices, $14.45.

If one inch of high grade insulation were added to the walls (corkboard is used as an illustration and is the basis of calculation), it would reduce the quantity of ice necessary to maintain this temperature difference to 90 pounds weekly, or 1,950 pounds for the summer. This would mean a saving of 1,450 pounds in ice and $6.15 in cost of operation. This added insulation would increase the initial cost of the ice box about $3.50, but it would pay for itself in about three months.

If two inches of corkboard were added to the insulation in box No. 1, the weekly ice meltage to overcome the radiation would amount

to but 65 pounds, or 1,370 pounds for the summer. This would mean a saving of about one ton of ice during the summer and would reduce the ice bill $8.65. To get this increased efficiency would add approximately $5.80 to the initial cost of refrigerator. Obviously, a good refrigerator will pay for itself in the ice it saves in three or four years.

TABLE LXXX.—SHOWING HOW THE EFFICIENCY OF A REFRIGERATOR MAY BE INCREASED, THE COST OF OPERATION REDUCED AND THE SAVING TO THE CONSUMER BY ADDING MORE INSULATION.

Box No.	Insulation	Heat Transmission Factor Per Sq. Ft. Wall Surface, B.t.u.	Ice Meltage for 150 Days to Maintain Temperature Difference of 20° F.	Ice Meltage Per Week.	Cost of Ice for 150 Days at $8.50 Per Ton.	Cost of Added Insulation.	Ice Saved by Added Insulation.	Money Saved by Less Ice Consumption.
1	2-7/8-in. boards, 2 sheets waterproof paper, 1-in. mineral wool	4.60	3,400 lbs.	158 lbs.	$14.45			
2	Insulation of box No. 1, plus 1-inch corkboard	2.64	1,950	90	8.30	$3.50	1,450	$6.15
3	Insulation of box No. 1, plus 2-inch corkboard	1.85	1,370	65	5.80	5.80	2,030	8.65

NOTE: Were the refrigerators in Rochester brought up to a state of efficiency they would save in lower ice bills to the consumer at least $350,000 yearly.

Conclusions: Neither the cellar nor pantry in the home are sufficiently cold to keep perishable foods from spoiling during the warm months of the year; therefore, every home should have a good refrigerator.

Only about half the homes in the city have refrigerators; the other half are compelled to depend upon the inadequate protection afforded by the cellar.

The majority of domestic refrigerators are inefficient because they consume too much ice and do not maintain a temperature low enough to prevent food from spoiling.

The chief explanation of their inefficiency is to be found in the lack of sufficient and proper insulation.

There are a large number of shoddy refrigerators on the market which contain no other insulation than a sheet or two of paper. They are sold chiefly to working people who can ill afford to use them, because they are both unsanitary and grossly uneconomical in the consumption of ice.

The waste from ice meltage because of improper insulation of refrigerators in Rochester homes (population of city, 230,000) amounts to 60,000 tons yearly, or about $350,000.

At least $100,000 more is wasted yearly in the present competitive system of delivery.

Unnecessary waste is now making refrigeration cost consumers from three to five times as much as it should.

There are certain simple directions which will be of assistance in selecting a refrigerator. If they are observed, the purchaser can at least avoid being defrauded.

One should insist upon seeing a section of the wall of the refrigerator which he contemplates buying. Honest manufacturers are always willing to let customers know the character of their wares.

Do not buy a box which does not bear the name and address of the maker, nor one sold only under the name of a retail dealer. If the manufacturer is ashamed to acknowledge his handiwork, you are justified in suspecting fraud.

TABLE LXXXI.—SHOWING THICKNESS OF WALLS OF REFRIGERATORS.

Section	Less than 2 in.	2 in. to 2¼ in.	2½ in. to 2¾ in. inclusive	3 in. or more.
Well-to-do	5	36	34	19
American laboring	9	23	4	3
Jewish laboring	17	42	8	1
German-American laboring	4	13	3	1
Italian laboring	0	0	0	0
Totals	35	114	49	24

Do not buy a box which contains less than three inches of good insulation, not including the wooden cases or the metal or tile lining.

Beware of impossible "vacuum," doubtful "dead air space," and no-good paper insulation.

Money invested in insulation will be returned many times in the saving of ice bills. Added insulation means not only economy in ice consumption, but also lower temperature in the refrigerator and the less spoiling of food.

A refrigerator is of little value which will not operate with reasonable care and ice consumption at 45° F. during the summer months.

There is a big field for the manufacturer who will put on the market an efficient ice box which can be sold at a price within the means of people in moderate circumstances.

Not one cellar was found cold enough to prevent the rapid decomposition of milk and meat. Living rooms were found to be even worse, therefore refrigerators are really a necessity. Only forty-two refrigerators of 300 examined were found as cold as they should be, while 177 of them were above 50° F., at which temperature they are of little value.

TABLE LXXXII.—SHOWING A NUMBER OF HOMES USING VARIOUS AMOUNTS OF ICE WEEKLY.

Section	50 lbs. or less	75 lbs.	100 lbs.	200 lbs.	201 to 300 lbs.	301 lbs. plus	Total
Well-to-do	0	3	24	79	28	15	149
American laboring	11	16	18	32	3	4	84
Jewish laboring	5	18	8	26	3	0	60
German-American laboring	3	5	10	19	0	0	37
Italian laboring	4	0	0	5	0	0	9
Totals	23	42	60	161	34	19	339

A good refrigerator should maintain an average inside temperature of not higher than 45° F., because food spoils rapidly at 50° F. This means a temperature difference of from 20° to 30° during the summer. A box which will not average 20° difference for the five warm months, with a reasonable consumption of ice, is no good. All of the better class of refrigerators use some efficient insulation. None of them use enough. The poorer makes use little or none, excepting a sheet or two of paper. Some manufacturers attempt to obtain cheap insulation by creating small air chambers of paper and wood, which they call "dead air space," a physical and practical impossibility in refrigerator construction. Such boxes are usually worthless.

A properly constructed ice box, to be economically operated, should have a wall of efficient insulating material at least six inches thick. Such a box at the current prices of ice, will have a theoretical efficiency of about 80 per cent The 149 refrigerators whose wall thickness is less than 2¼ inches, even were they made of the best possible construction, could not have an efficiency above 40 per cent. The remaining seventy-eight refrigerators with walls averaging less than three inches, could not have an efficiency of above 50 per cent. As a matter of fact, with the shoddy and imperfect insulating materials used, most of the ice boxes in common use rate far below their theoretical efficiency.

It is interesting to note that Italian working people use very little ice. It was observed that they avoid very largely the use of perishable foods requiring refrigeration in the home. Thus, condensed milk is used largely in place of fresh milk and preserved meat in place of fresh meat. Jewish people use much milk and therefore much ice.

Unfortunately these people get the benefit of not much more than 20 to 30 per cent of the ice they buy because of the defective ice boxes. There are about 55,000 families in Rochester. They use approximately 100,000 tons of ice yearly in their homes. Beyond all question more than 60,000 tons of this ice is wasted, entailing a loss to these consumers of at least $350,000.

TABLE LXXXIII.—SHOWING NUMBER OF MONTHS ICE IS USED DURING YEAR BY HOMES IN VARIOUS SECTIONS OF ROCHESTER.

Section	1 mo.	2 mo.	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 to 12 mos.
Well-to-do	0	2	5	15	22	24	15	8	33
American laboring	1	6	10	14	21	3	4	4	3
Jewish laboring	0	4	16	26	47	15	5	1	1
German-American laboring	1	1	4	8	15	0	0	0	1
Italian laboring	0	0	2	0	0	0	0	0	0
Totals	2	13	37	63	105	42	24	13	38

NOTE:—This table shows, among other things, the seasonal character of the use of ice. This adds greatly to the cost of distribution, because it necessitates a large investment in equipment, most of which is idle during one-half of the year.

There is a different dealer for each five to fifteen consumers on every street in Rochester, a tremendously wasteful and uneconomical method of distribution. If an economical system of distribution were to replace the present method, a saving could be made to the consumer of at least $1.00 per ton or $100,000 yearly for the whole city.

TABLE LXXXIV.—SHOWING THE OVERLAPPING OF ROUTES OF DEALERS IN THE DISTRIBUTION OF ICE.

Street	Number of consumers	Number of dealers supplying consumers
Dartmouth	39	5
Baden	48	8
Frank	17	7
Kenwood	47	6
Adams	21	7
Oxford	25	3

Table LXXXV gives a summary of the data on weekly amounts of ice, cost of ice per year and relative temperatures. From the "Study of Refrigeration in the Home and the Efficiency of Household Refrigerators," by John R. Williams.

TABLE LXXXV.—DATA FROM STUDY OF HOUSEHOLD REFRIGERATORS IN ROCHESTER, N. Y.

Weekly Amounts Ice		Cost of Ice per Year	
50 lbs or less	7%	Under $5	23%
51 to 75	12%	$ 5 to $10	43%
76 to 100	18%	$10 to $15	15%
101 to 200	47%	$15 to $20	7%
201 to 300	10%	$20 and over	12%
301 and over	6%		100%
	100%		

TEMPERATURES

In Refrigerators		Living Rooms		Cellars	
Below 45°	14%	Below 60°	0%	Below 55°	0%
45 to 50°	27%	60 to 70°	42%	Below 60°	8%
50 to 60°	51%	Above 70°	58%	Above 60°	92%
Over 60°	8%				

Bureau of Standards' Tests on Refrigerators.—The United States Bureau of Standards has conducted certain tests on refrigerators. This was reported in the Bureau of Standards Circular No. 55. The following extract and Table LXXXVI gives the principal data in this bulletin:

TABLE LXXXVI.—RESULTS OF TESTS OF REFRIGERATORS.

Refrigerator Number	Room Temperature	Coldest Inside Temperature	Warmest Inside Temperature	Weight of Ice Melted per Hour	Heat Transmission per Hour B.t.u. per Sq. Ft. per Deg. F.	Air Circulation, Cu. Ft. per Min.	Inside Volume	Average Weight of Ice in Box During Test.
	Deg. F.	Deg. F.	Deg. F.	Lbs.		at 60° F.	Cu. Ft.	Lbs.
1	92.1	52.7	64.4	1.50	0.14	21.4	16.5	42.2
2	91.8	57.2	72.1	1.78	0.21	19.6	18.1	37.1
3	91.3	49.3	70.7	1.63	0.19	12.7	18.0	41.1
4	90.0	46.6	70.3	1.43	0.14	10.1	18.0	43.2
5	89.6	49.5	68.7	1.41	0.15	12.1	16.5	41.2
6	91.1	55.9	69.8	1.54	0.18	18.5	18.2	42.7
7	91.5	46.9	66.2	1.63	0.15	13.8	17.1	41.8
8	92.0	44.1	64.0	1.59	0.14	13.0	17.3	41.7
9	93.1	51.8	66.6	1.65	0.19	18.5	19.0	40.7

Table LXXXVI gives some results of tests on nine refrigerators of average quality or better, where the air in the refrigerator averages nearly as much warmer than the ice as it is cooler than the air out-

side; thus, with a room at about 90°, the lowest temperatures inside the refrigerators range from 44° to 57° and the highest 64° to 72°. It has been found (Bulletin No. 98 of United States Department of Agriculture) that in milk kept at 60°, about fifteen times as many bacteria will develop in one day as in milk kept at 50° F., and much the same is true of many other foods. It is important, therefore, to find the coldest places in a refrigerator (usually near where the air leaves the ice chamber) and use these places for foods such as milk and meats which need to be kept as cool as possible to prevent spoiling.

The outside dimension of the refrigerators listed in Table LXXXVI averaged 24 inches deep, 40 inches wide, and 50 inches high.

The figures in the column headed "Heat transmission" gives the amount of heat in British thermal units (B.t.u.) that passes through every square foot of the outside surface of the refrigerator in an hour when the room temperature is one degree F., higher than the average inside temperature of the refrigerator. If the room temperature were ten degrees higher than the inside of the refrigerator, ten times this amount of heat would pass through every square foot of the walls.

The sixth column of Table LXXXVI, headed "Heat Transmission," illustrates the relative merits of the different refrigerators, since it tells directly how much cooling is wasted, that is, how much heat enters the refrigerator through the walls per hour for each square foot of wall, and for each degree difference in temperature between the inside and outside. For instance, to hold the average temperature inside refrigerator No. 1, 30 degrees below the temperature outside would require two-thirds as much ice for No. 2. To be sure, No. 2, though a much poorer refrigerator, used only about one-fifth more ice than did No. 1, but its inside temperature was not nearly so low, and therefore it would not have kept food fresh so long as No. 1.

Slow melting of the ice does not necessarily indicate a good refrigerator. Unless the ice melts, it can absorb no heat, and is therefore of no use in a refrigerator. Protecting the ice in a refrigerator by covering it up is a good way to save ice but a poor way to save food. The only proper way to use less ice is by using a refrigerator with better insulated walls, and by opening the doors as seldom and for as short a time as possible.

N. Y. Tribune Institute Tests.—The N. Y. Tribune Institute reports the ice consumption, as determined by twenty-seven tests on well known standard refrigerators, to be between 0.00407 and 0.0100 pounds of ice melted per hour per cubic foot of food storage space, per degree of difference in temperature between room and refrigerator. These values in B.t.u. would be 0.58608 and 1.44 respectively. The results of these tests are shown by tables LXXXVII and LXXXVIII.

Tests of Balsa Refrigerators.—Household refrigerators of an improved design constructed entirely of balsa wood, with an interior and exterior coating of a magnesite composition applied in plastic form, were built by the American Balsa Co. The tests described in the following were made on the 100-lb. ice capacity side icer type, by Dr. M. E. Pennington in February, 1923. The results are shown graphically in Figs. 131, 132, and 133. The summary of the performance test of the balsa refrigerator of the household type is shown in Table LXXXIX. From the last column of this table, it will be noted that an average of 3.16 B.t.u. were transmitted per 24 hours per degree of temperature difference per square foot of radiating surface.

TABLE LXXXVII.—TESTS BY NEW YORK TRIBUNE INSTITUTE.

Insulation	Average Room Temperature Deg. F.	Average Food Compartment Temperature Deg. F.	Average Ice Consumption Pounds per Hour.	Radiation Area Sq. Ft.	Heat Loss B.t.u. per Hour	Heat Loss B.t.u. per Sq. Ft. per Day per Degree Temperature Difference
Fibre Board and Air	74.6	55.3	0.746	33	123	4.7
Granulated	69.6	43.1	0.826	44.5	127	2.6
Cork and Wood	71.0	45.4	1.085	44.5	168	3.5
Flaxinum, Wood,	68.1	46.6	0.691	33	108	3.85
Felt and Paper	71.0	47.5	0.792	33	125	4.05
	7.9	49.7	1.279	40.6	198	4.0
	79.7	49.8	1.539	40.6	253	4.9
Fibre Board and Air	69.3	47.0	0.763	28.2	120	4.6
	70.8	47.6	0.750	28.2	118	4.4
Mineral Wool, Paper	67.5	47.6	0.739	36.9	117	3.8
and Wood	68.4	48.0	0.741	36.9	117	3.7
Wool Felt, Paper,	67.6	48.2	0.582	21.2	92	5.4
Air and Wood	66.7	46.5	0.511	21.2	80	4.5
Flax Fibre, Wood	69.3	47.8	0.891	39.9	141	4.0
and Air	70.5	48.0	1.085	39.9	171	4.6
Iron, Cork, Air and Wood	72.3	47.2	0.828	32	124	3.7

NOTE:—Radiation area is the average between the outside and inside surfaces of the cabinet. The heat loss includes both the effect of melting ice and heating the resulting ice water.

TABLE LXXXVIII.—ICE REFRIGERATOR TESTS BY NEW YORK TRIBUNE INSTITUTE.

Test Method	Average Room Temperature Deg. F.	Average Food Compartment Temperature Deg. F.	Radiation Area Sq. Ft.	Heat Loss B.t.u. per Hour	Heat Loss B.t.u. per Sq. Ft. per Day per Degree Temperature Difference
Test A, Fibre Board and Air					
Ice	55.3	74.6	33.	123.	4.6
Non-Circulating Heat	102.	77.	33.	169	4.9
Test B, Granulated Cork and Wood					
Non-Circulating Heat	99.	71.4	35.2	185.5	4.6
Circulating Heat	95.	68.0	35.2	215.	5.4
Test C, Granulated Cork, Air and Wood					
Ice	47.2	72.3	32.	124.	3.75
Circulating Heat	104.	62.6	32.	221.	4.0

NOTE:—Each set of readings is the average value of two tests. Radiation area is the average between the outside and inside surfaces of the cabinet.
Heating element is shielded to reduce heat loss to walls by radiation.
In heat tests a "dummy" ice cake was used to offer similar resistance to air circulation as in ice melting test.
A small fan was used in the circulating heat test.
These tests indicate that the non-circulating heat method of testing gives results corresponding very closely to the results by the ice melting test. The electric heating element is placed in the food compartment and, of course, produces some air circulation inside the cabinet. The electrical has many advantages over the ice melting method.

The purpose of the test was to determine ice meltage, box temperatures, and efficiencies under several conditions of icing as indicated in the three following tests:

Test "A" was an average of four consecutive 24-hour test periods. Ice was replaced at beginning of each test period by new cake of same approximate, original weight. Results graphically shown on Fig. 211.

Test "B" was an average of two consecutive 48-hour periods. Ice replaced at beginning of each test period by new cake of same approximate original weight. Results graphically shown on Fig. 212.

Test "C" was a continuous 96-hour test period without re-icing. The results are graphically shown on Fig. 213.

Box Specifications.—Box was designed and built by the American Balsa Co., for the National Association of Ice Industries, Dr. M. E. Pennington, consulting and advisory technical expert for the association:

DIMENSIONS OF REFRIGERATOR

	Width	Depth	Height
Outside dimensions over all	35½-in.	21 -in.	50 -in.
Inside dimensions	30⅛-in.	15⅝-in.	38⅝-in.
Ice compartment (Including Baffle)	14⅛-in.	15⅝-in.	27 -in.

Milk compartment	13 -in.	15⅝-in.	11⅝-in.
Food compartment	16 -in.	15⅝-in.	38⅝-in.

DOOR OPENINGS IN REFRIGERATOR

	Width	Depth	Height
Ice compartment	12 -in.	......	25 -in.
Milk compartment	12 -in.	......	10⅛-in.
Food Compartment	13⅝-in.	......	38⅝-in.

The box is lined and covered by American Balsa Company's synthetic stone, applied directly to 2-inch Balsa insulation, making a seamless lining and covering finished in white enamel inside and out. Baffle, shelves ice tray and pan, bunker and drain pipe are entirely removable.

The tests were made at the Bronx Plant of the American Balsa Co., in experimental refrigerator test room where room temperatures could be reasonably controlled.

Temperature Observations.—Room temperatures and averages were determined from S. & B. recording thermometer. Reading averaged hourly from recording chart. Leads & Northrup resistance thermometers and reading box were used to determine all box temperatures. These thermometers read to 0.1 degree and were calibrated before and after tests. Box temperatures were observed at the following locations:

1. Warm air inlet.
2. Middle food compartment.
3. Bottom food compartment.
4. Cold air drop.
5. Middle milk compartment.
6. Middle top shelf.

Average temperature, middle food compartment, was determined by averaging middle milk compartment and middle top shelf compartment temperatures. This average temperature was used in all calculations.

Ice Meltage.—Rates of ice meltage were determined from actual meltages, by removing ice from box at end of 24-hour periods and weighing. After weighing, cake was replaced or new cake substituted as conditions of test demanded. Check meltages were taken by weighing drip water, but these figures were not used in calculations. Readings were taken at 9 a. m. and 10 a. m., at noon and at 3 p. m. and 5 p. m. Twenty-four hour test and ice weighing intervals were from 10 a. m. to 10 a. m.

Results.—Results of tests are shown graphically in Figs. 214, 215 and 216 and Table LXXXIX, and comprise the complete results of this test, which is the American Balsa Company's Laboratory Experiment No. 258.

TABLE LXXXIX.—SUMMARY OF PERFORMANCE TESTS OF

Balsa Refrigerator, Household Type Experiment 258, Tests A, B and C. Insulation: Wood, flax fibre, dead air space, wool felt, paper, and waterproof paper.

	Ice Cap. Lbs.	Total Vol. Cu. Ft.	Vol. Ice Comp. Cu. Ft.	Vol. Food Comp. Cu. Ft.	Per Cent Ice Comp. to Total Vol.	Per Cent Ice to Food Compartment	Rad. Surf. Total Inside Area	Duration of Test Hrs.	Average Room Temperature	Average Food Compartment Temperature	Average Temperature Difference	Ice Melted Lbs. per Hr.	Ice Melted per Hr. per Deg. per Cu. Ft. Food Comp. Vol.	Ice Melted per Hr. per Deg. per Sq. Ft. Rad. Surf.	B.t.u. Loss per 24 Hrs. per Deg. per Sq. Ft. Rad. Surf.
Test A	100	10.53	3.45	7.08	32.8	48.8	31.02	96	72.1	43.6	28.6	.802	.00397	.000907	3.13
Test B	100	10.53	3.45	7.08	32.8	48.8	31.01	96	71.7	44.1	27.7	.802	.00409	.000934	3.24
Test C	100	10.53	3.45	7.08	32.8	48.8	31.02	96	71.8	45.3	26.5	.737	.00392	.000895	3.10

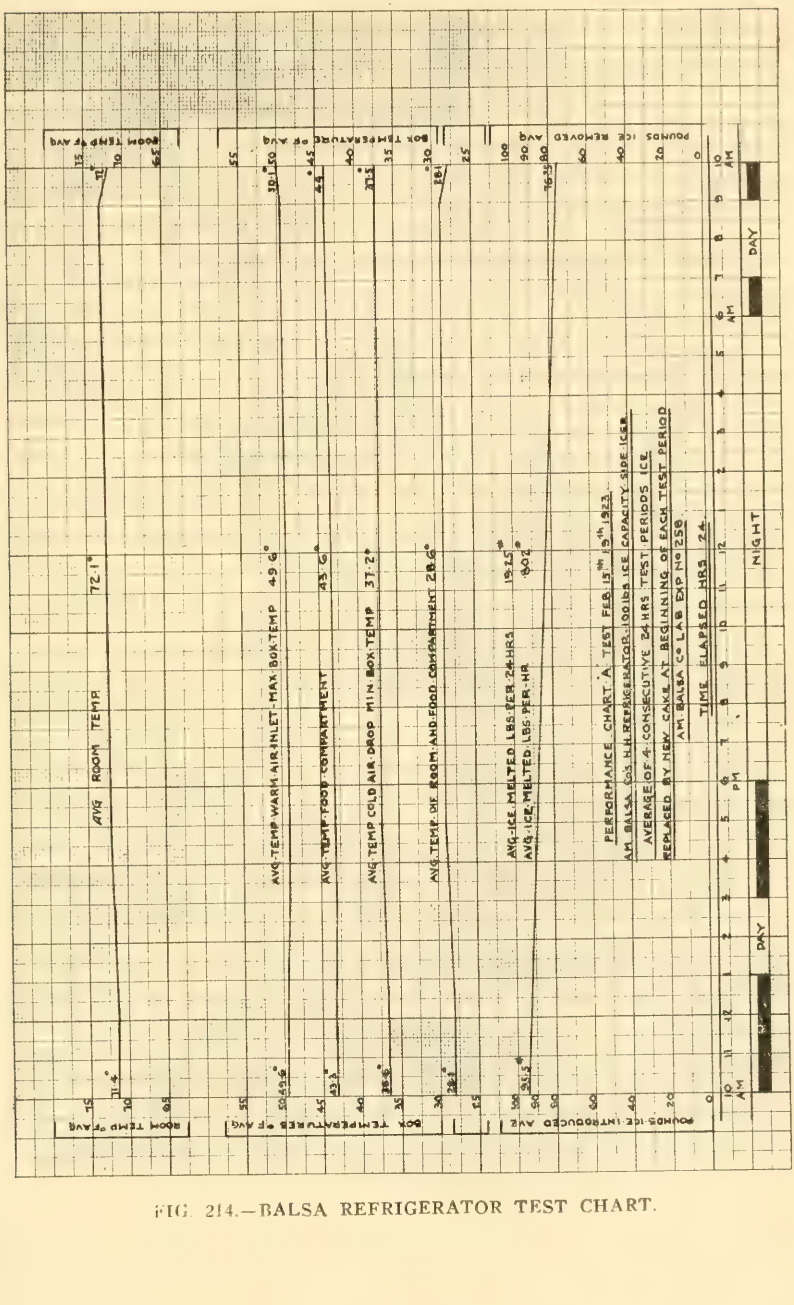


FIG. 214.—BALSA REFRIGERATOR TEST CHART.

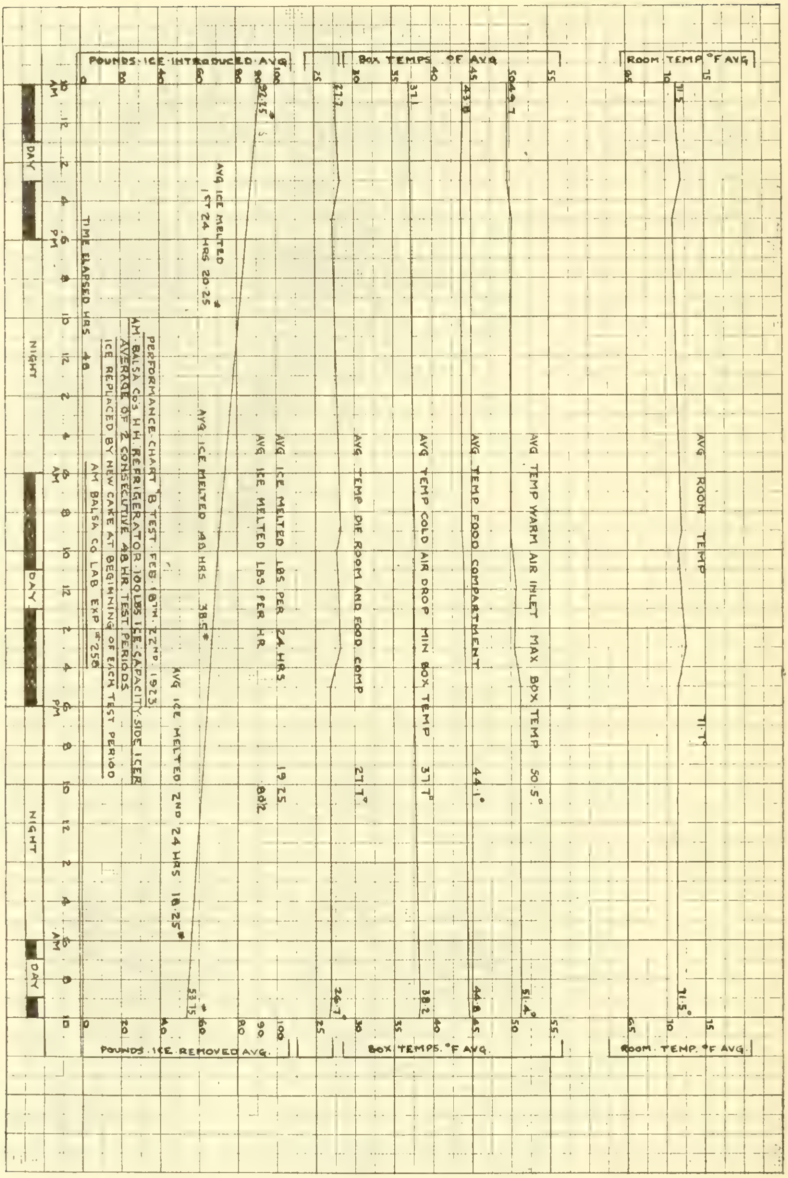


FIG. 215.—BALSA REFRIGERATOR TEST CHART.

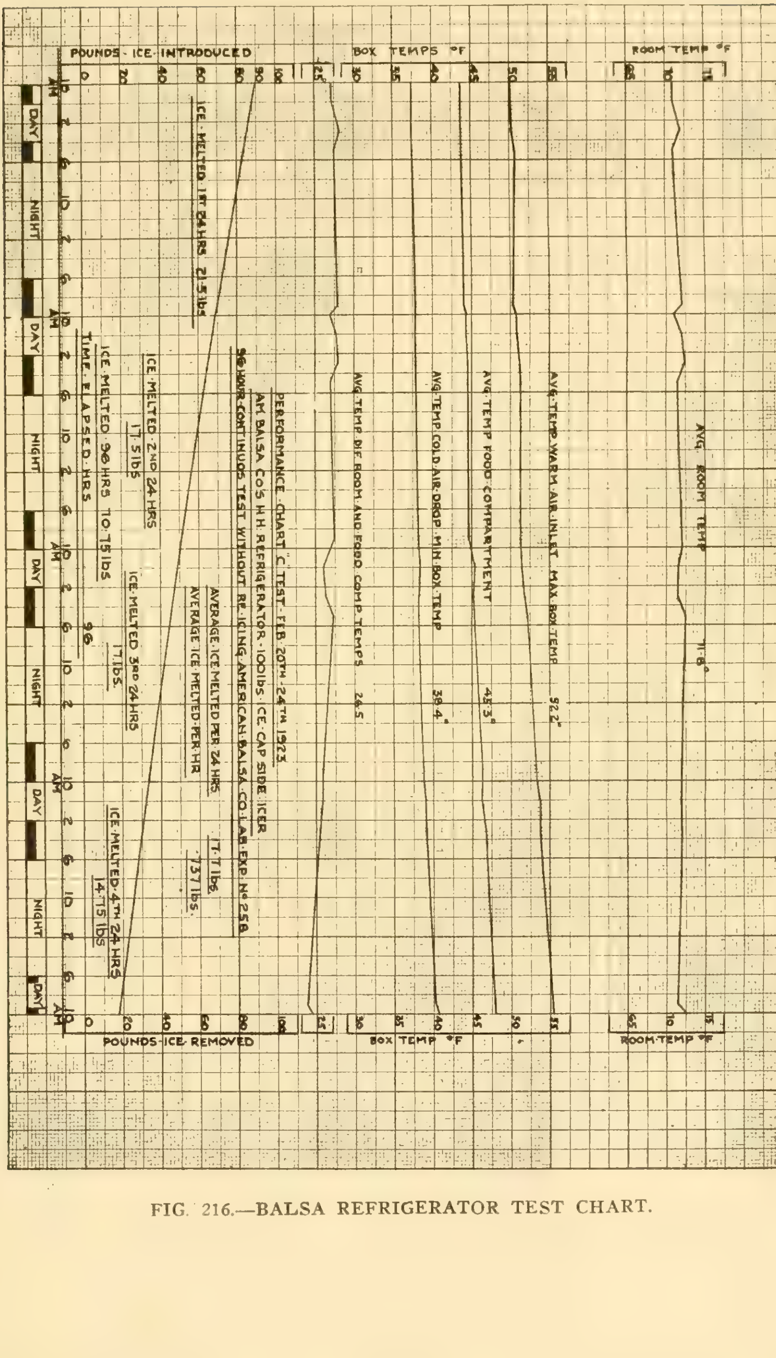


FIG. 216.—BALSA REFRIGERATOR TEST CHART.

Tests at University of Illinois.—An exhaustive test in the University of Illinois laboratories compared three refrigerators purchased from the stock of local dealers. One was with granulated cork insulation, while the other two used mineral wool and other insulations. The lower melting rate per hour, proved that the refrigerator with its granulated cork insulation was the most economical refrigerator for general use. The figures are as follows:

	Hours Tested	Ice Melt	Melt Rate Per Hour
No. 1. (Graulated Cork)	219.0 hours	109¼ lbs.	0.498 lbs.
No. 2. (Mineral Wool)	119 9 hours	71 lbs.	0.592 lbs.
No. 3. (Mineral Wool)	168.95 hours	141¾ lbs.	0.839 lbs.

Assuming that a refrigerator is used for six months of each year, and that the ice will cost fifty cents per cwt., the cost of the ice for the year will be as follows:

No. 1—2,151 lbs. of Ice at 50c	$10.75
No. 2—2,557 lbs. of Ice at 50c	12.79
No. 3—3,624 lbs. of Ice at 50c	18.12

Tests by Good Housekeeping Institute.—The Good Housekeeping Institute, conducted by the Good Housekeeping Magazine of New York City, reports the following result of a test on Bohn Syphon refrigerator:

The refrigerator is well-constructed throughout, and provided with a one-piece seamless lining with rounded corners, that is, a smooth, hard surface, easily kept clean and in a sanitary condition. In tests of one hundred consecutive hours duration, the following results were obtained.

Average Food Compartment Temperature	Average Room Temperature	Averae Ice Consumption Lbs. Per Hour
45.5 F.	75.1 F.	0.750
41.2 F.	68.1 F.	0.613

The method of rating was as follows:

Construction	Good
Efficiency of Design	Very Good
Efficiency of Operation	Very Good
Initial Cost	Medium
Upkeep Cost	Low

The refrigerator scores 94 points.

The detailed specifications of this cabinet are as follows:

	Width Inches	Depth Inches	Height Inches
Outside	36	21	47
Large Provision Chamber	13¼	14¼	32

Small Provision Chamber	15	14¼	9¾
Ice Chamber	13¾	15⅝	18
Ice Chamber Door Opening	11¼	....	14⅞

Ice Chamber Capacity, 100 pounds
Shipping Weight, 335 pounds

Total Volume Overall	20.5 Cu. Ft.
Food Storage Space	4.7 Cu. Ft.
Ice Storage Space	2.2 Cu. Ft.
Shelf Area	6.7 Sq. Ft.

Insulation: Wood, flax fibre, dead air space, wool felt, paper, and waterproof paper.

The pounds of ice melted per hour per cu. ft. food storage space per degree temperature difference were as follows:

First Test	0.0054
Second Test	0.00484

Tests on Ice Refrigerators.—The following data, on testing of ice refrigerators, has been published by the Davison All-Steel Refrigerator Co., in Montreal, Canada. The room temperature during the test was 68° F.; one piece of ice weighing initially sixteen pounds was used, and the refrigerator tested was the Frost River type No. 24. The piece of ice lasted for sixty-eight hours and the lowest temperature obtained in the food chamber was 48° F., the insulation consisting of linofelt and air space. The outside volume of the refrigerator was seventeen cubic feet. The food compartment was 5.65 cu. ft. The shelf area was 8.2 sq. ft. and the total shipping weight was 162 pounds.

TABLE XC.—REFRIGERATOR TEST.

Date	Time	Temperature of Food Chamber	Amount of Ice
May 9	2 P. M.	66	16 Pounds
	10 P. M.	54	
	2 P. M.	52	
	4 P. M.	52 (Temp. Ice Chamber 42)	
May 10	12 Noon	50	
	Midnight	50	
	7 P. M.	48	
May 11	7 A. M.	48	
	12 Noon	49	
May 12	7 A. M.	58	
	12 Noon	60 Out of Ice	

Tests on Average Household Refrigerators.—Table XCI gives the result of the tests on fifteen average household refrigerators used in homes. From this, it is interesting to note that the average temperature inside of the refrigerator

at the middle shelf was 55°, that the average number of pounds of ice consumed per day was 29.6 and that the average cost of ice per day per refrigerator was 14.8 cents.

TABLE XCI.—TEST ON FIFTEEN AVERAGE HOUSEHOLD REFRIGERATORS IN USE IN HOMES.

Average Room Temperature	79 degrees
Average Temperature Inside Refrigerator at Middle Shelf	55 degrees
Average Pounds of Ice Consumed per Day	29.6 lbs.
Cost of Ice	56 cents per 100 lbs.
Average Cost of Ice per Day for Each Refrigerator	14.8 cents

Refrigerator Score Card.—A refrigerator score card for the purpose of comparing different kinds of refrigerators has been prepared by F. O. Riek, of the Rhinelander Refrigerator Co., who has used some data and suggestions contained in a score card for refrigerators originally published in the Chicago Tribune by Dr. W. A. Evans, and is as follows:

REFRIGERATOR SCORE CARDS

Name of manufacturer.......................................

Name or other method of designating refrigerator..................

Points of Score	Perfect	Score
1. Temperature of Food Chamber	45	
2. Ice Economy or Efficiency	20	
3. Humidity	8	
4. Circulation	7	
5. Interior Finish	12	
6. Drainage	3	
7. Exterior Finish	5	
Total	100	

Explanation of Score Card:

1. *Temperature Test*: Standard conditions for test demand refrigerator to be in a room free from drafts and at an even temperature. Box should not contain food. Door should not be opened except when taking readings. Refrigerator should be cold throughout. Have the ice chamber full. Place thermometer in the center of the food chamber. Make four readings at intervals of not less than one hour. Take room temperature four times.

Rate as follows:

When temperature is:	The score will be under:
40° F.	45
45	43
50	36
55	23
60	9
over 60	0

2. *Ice Economy*: Refrigerator should be cold when test is begun. Weigh ice at the beginning of test. Weigh ice left at termination of test. Obtain data:

(a) Temperature of food chamber.

(b) Temperature of room.

(c) Square feet of surface exposure calculated on exterior dimensions.

To determine substitute in the following formula:

$$R = \frac{I\ 144}{S\,(T-t)}$$

where R equals "efficiency" of rate of heat transmission which may be defined as the number of B.t.u. which pass through one square foot of surface daily when the difference between the surface is 1° F.
I equals the number of pounds of ice melted daily.
144 equals B.t.u. required to melt one pound ice.
S equals surface exposure.
T equals average atmospheric temperature.
t equals average temperature of food chamber.

Rate as follows:

Where R equals	1.13	rate 20
	1.63	rate 18
	2.00	rate 16
	2.33	rate 14
	2.66	rate 12
	3.00	rate 10
	3.33	rate 8
	3.66	rate 6
	4.00	rate 4
	4.33	rate 2
	4.66	rate 1
	5.00	rate 0

3. *Humidity*: In making humidity tests a wet and dry bulb thermometer should be used. At least four readings are to be taken at intervals of one hour.

See Bureau of Standard tables for readings calculated upon differences in temperatures of wet and dry thermometers. Score as follows:

Percentage humidity ranges	
55 to 65 rate	8.0
65 to 75 rate	7.5
45 to 55 rate	7.5

40 to 45 rate	7.2
75 to 80 rate	6.4
30 to 40 rate	6.0
80 to 85 rate	4.8
20 to 30 rate	4.8
85 to 95 rate	2.4
90 and over rate	0.0
20 and under rate	0.0

4. *Circulation of Air*: Note Whether the box can be ventilated. Credit for possibility for ventilating. Credit for probability that cold air will pass from ice to food and air returns from the food to the ice. If any wall is moist substract at least two. If air cannot reach ice, subtract two.

5. *Interior Finish*: Ease of cleaning refers to cleaning of food chamber, all shelves therein, and the drain pipes. If ease of cleaning is ideal, value six. If finish is hard and non-absorbent, value three. If color is white, value five.

6. *Drainage*: A. See that the trap in the drain pipe works. If there is proper trapping, value two. If there is proper tubing, value one.

B. Construction of Refrigerator:

1. Arrangement of chamber—show diagram.
2. Temperature maintained.
   a.—Ice chamber.
   b.—Food chamber side.
   c.—Food chamber below.
3. Insulation—show diagram.
4. Economy of space in food chambers.

C. Cost:

1. First Cost.
2. Maintenance Cost.

D. Manufacturer's Claims:
Does the manufacturer over-emphasize minor details in advertising his refrigerator?

References:
Lynde, "Household Physics."
Bureau of Standards Circular No. 55, Measurements for the Household.
Manufacturers' Catalogs.
Good Housekeeping Institute.
Good Housekeeping Magazine, May, 1914.
A study of Refrigeration in the Home and the Efficiency of Household Refrigerators.—J. R. Williams.

Determining the Efficiency of a Refrigerator Wall.*—To determine the heat transmission value of a wall in B.t.u.'s per square foot per degree Fahrenheit temperature difference, it

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*From Rhinelander "Handbook of Refrigeration."

is necessary to know three things. That is, when structure of wall is not known.

These three factors are:

1. Square feet of surface exposure calculated the mean transmission surface on exterior dimensions and also interior surface.

2. The weight of ice melted in 24 hours.

3. The difference between the average temperature of inside refrigerator food chamber and room temperature.

To find the average or "mean transmission surface" get, first of all, the square feet of surface calculated on exterior dimensions. Then get total square feet inside by measuring inside surface. Average of two square surfaces—exterior and interior is mean transmission surface.

The weight of ice melted is determined by weighing the empty water pan at start of test, then at conclusion of 24 hour test weighing the water and pan, deducting the initial weight of empty water pan.

To get temperature tests outside and inside standard conditions for test require refrigerator to be in a room free from drafts and at fairly even temperature. Box should not contain food. Doors should not be opened; except when taking readings. Refrigerator should be thoroughly chilled, at least 48 hours before making test. Have ice chamber full. Place thermometer in the center of food chamber and make at least four readings at about three hour interval. Take room temperature at same time. Average all food temperatures and outside room temperature and then find difference between the two averages.

Use following formula:

$$X \text{ equals } \frac{I\ 144}{S\ (T-t)}$$

I equals ice melted.
144 equals B.t.u. required to melt one pound of ice or Latent Heat.
S equals mean transmission surface.
T equals average room temperature.
t equals average temperature of food chamber.

X equals number of B.t.u.'s passing through one square foot of surface per degree Fahrenheit temperature difference.

CHAPTER XII.

PRESERVATION OF FOODS IN THE HOME

Influence of Temperature on Bacteria in Foods.—Temperature has an important influence on the growth of bacteria. Most bacteria, yeasts, molds, and related organisms grow best at a temperature between 68° and 122° F., and do not grow at a temperature below 45° to 55° F. Cold retards their growth and tends to preserve these microorganisms as well as the food unchanged. It is well known that foods removed from cold storage are inferior in keeping qualities to the corresponding fresh foods. Freezing decreases the number of bacteria but does not immediately kill them. Most molds are easily destroyed by freezing.

Bacteria will multiply in milk as long as it is not frozen entirely solid. Milk of good quality will stay sweet and in perfect condition for more than a week if it is held at a temperature slightly above the freezing point. The temperature at which it is held determines the rate and kind of decomposition which takes place. Milk should stay sweet when stored properly for at least ten days.

Heating milk to 212° F. for about fifteen minutes will kill all except a few spores of bacteria. Several heatings are necessary to kill all vegetative cells.

Most of the living bacteria in butter diminish when it is refrigerated—a few kinds may multiply. There is a slow increase in acidity. The bacteria and chemical composition remain practically the same in frozen butter. The keeping qualities of butter depend largely upon the cleanliness and the quality of the materials used in making it.

Fruits and vegetables are usually adapted to preservation for short periods at ordinary temperatures. The best storage conditions for them is at temperatures slightly above the freezing point and a humidity of 60 per cent saturation. A higher humidity favors the development of molds.

Bacteria do not multiply in ice as they have nothing upon which to feed. When liquids are frozen solid the number of bacteria decreases very slowly.

Effect of Refrigeration Upon Foods.—Cold does not destroy the microbes in food but retards their activity and growth. The decomposition of foods is caused by the action of their own enzymes and more frequently by the activity of bacteria, yeast, and molds.

Fruits and vegetables should be stored at a temperature slightly above 32° F. and in a humidity at about 60 per cent of saturation, in order to diminish evaporation without developing molds. The best storage condition to prevent the development of bacteria and molds, is to keep the fruits and vegetables in a very constant humidity and a very constant temperature, slightly above 32° F.

Laboratory tests prove that the bacteria which cause food decomposition have their growth greatly retarded below a temperature of 45° F. Between 45° and 50°, they grow at a slightly greater rate, and above 50° F. the bacteria multiply prolifically. Perishable foods should be stored in a temperature not over 50° F. and preferably below 45° F.

It is important that foods be used shortly after they are removed from cold storage. Cold foods often condense moisture from the atmosphere on their surface, and it is well known that their keeping qualities are then inferior to corresponding fresh foods.

Ice and Its Relation to Food.—Dr. Leonard Keene Hirschberg, writing in the *Chicago Evening Post*, gives the following on the use of ice as a means of preservation of food:

Ice checks the growth of living things to the extent that it almost causes the smallest forms of vegetable and animal creation to cease

to exist as life. Usually, it does not kill, but it produces a condition of latent life, like the winter sleep of bears, beavers, snakes, and other creatures.

Ice thus becomes a help to man. It checks the birth, growth, multiplication, vitality, virulency, and noxious activity of bacteria, molds and other such living things which spoil foods, and especially those such as the typhoid bacilli.

The reason milk and so much food spoils in summer is because these unseen colonies of bacteria and other vegetation multiply and incubate in the warmed food. Its texture, appearance, color, taste, flavor, odor, and value thus depreciate.

Bacteria are everywhere on even the cleanest hands, but many more are on soiled hands and dirty nails. Flies, ants, roaches, dust, wind, and water carry them.

Ice keeps down the growth of bacteria, but you can only prevent them from spoiling food or causing disease by being sure of pure milk, pure water, sterile vessels, and dishes. You should scald everything, including linens.

Even where foods are apparently not spoiled, such germs as those of dysentery, scarlatina, colds, tuberculosis, typhoid, diphtheria, influenza, botulism, and others may be germinating, just as a seed does in summer in fertile soil.

Scrupulous cleanliness or surgical cleanliness means more than soap and water cleanliness. It means freedom of everything from germs by asepsis and sterlization.

Sunlight, harmless disinfectants, sterlization or boiling keep down to a minimum the growth of germs.

Ice boxes, refrigerators, cold storage, porous earthenware, coolers, vacuum jacketed bottles, and other measures to keep food in summer well below 45°, all help to keep it free of any great increase and growth of bacteria.

Perhaps more difficult to keep and most important in the summer kitchen is milk. If there are infants about, their very lives depend upon milk free of bacteria.

Sour milk is not the only milk teeming with bacteria. Indeed, the sweetest and richest milk is often alive with deadly germs, which becomes planted in the little one's intestines.

Unless milk goes directly into sterlized bottles from a cow whose hide is made germ-free by disinfectants, by the time it passes through hands, cans, bottles, and nipples it has millions of dangerous bacteria in it.

The only safe way to keep milk in summer is to boil it twenty minutes and put it on ice at once, and keep it there until given to the child.

In summer especially, but also in the winter, ice should not be spared around the house. It is one of the cheapest and most useful of modern conveniences. As a health preserver, it is seldom given its due need of praise.

Care of Milk in the Home.—Farmers' Bulletin No. 1207 of the United States Department of Agriculture gives the following dissertation on the care of milk in the home:

No matter how well milk has been handled up to the time it is delivered to the consumer, it can not be expected to keep well if it is then carelessly treated. Milk should be kept clean, covered, and cool, these three points, consumer as well as producer should never disregard.

In towns and cities, the best way of buying milk is in bottles. In this form it can be kept clean and cool more easily during delivery and is much more convenient to handle. Dipping milk from large cans and pouring it into customers' receptacles on the street with the incident exposure to dusty air, is bad practice. Drawing milk from the faucet of a retailer's can is not quite so bad as dipping, but the milk is not kept thoroughly mixed and some consumers will receive less than their share of cream. By whichever of these methods the milk is measured, it should be delivered personally to some member of the household, if possible, or a covered vessel may be set out, such as a bowl covered with a plate, or better still a glass jar, used for no other purpose, with a glass lid but without a rubber. Under no circumstances should an uncovered vessel be set out to collect thousands of bacteria from street dust before the milk is poured into it. Money and paper tickets are often more or less soiled; hence neither should be put into the can, bowl or jar.

Sometimes milk is delivered as early as 4 o'clock in the morning, remains out of doors in a place exposed to sunshine and perhaps accessible to cats and dogs until 9 or 10 o'clock. This is wrong. If the milk cannot conveniently be brought into the house at once, the delivery man should be asked to leave it in a sheltered place or in a covered box provided for the purpose. Even a temporary rise in the temperature of milk will help the development of bacteria that have been held in check by keeping the milk cool, and domestic animals rubbing against a milk container may contaminate it with bacteria dangerous to health.

As soon as possible after delivery, milk should be put in a cool, clean place and kept there until used. It deteriorates by exposure to the air of pantry, kitchen, or nursery. Unless it is in the bottle into

which it was put in the dairy, it should be poured into a freshly scalded vessel and covered.

The best temperature for keeping milk is 50° F. or less, and good milk kept that cool should remain sweet for 12 hours at least, and ordinarily 24 hours or more, after it reaches the consumer. If ice cannot be obtained, an iceless refrigerator or some such device is a help even though a temperature as low as 50° F. can rarely be maintained in it.

In the ordinary refrigerator, unless the milk container is in actual contact with the ice, the milk will be colder at the bottom of the refrigerator than in the ice compartment, for cold air settles rapidly. The refrigerator should be kept clean and sweet at all times. Inspecting it thoroughly at least once a week is a good plan, to see that outlet for water from the melting ice is open and that the space under the ice rack is clean. Also the food compartments should be scalded every week. A single drop of spilled milk or a particle of neglected food will contaminate a refrigerator in a few days.

Sometimes in very hot weather housekeepers complain that, in spite of all precautions, milk sours quickly, even in the refrigerator, which, although cool in contrast with the heat outside, is really not cold enough to check the growth of the bacteria in milk. If a thermometer placed inside registers more than 50° F., the fault cannot be laid entirely to the quality of milk.

Milk should be kept covered to exclude not only dirt and bacteria but also flavors and odors, which it readily absorbs. It should be kept away from foods of strong odor, such as onions, cabbage, or fish.

Bottled milk should be kept in the bottles in which it is delivered until needed for use. In fact, from a sanitary standpoint, serving milk on the table in the original bottles is excellent practice. In any case a milk bottle, especially the mouth, should be cleaned carefully before the milk is poured from it, and only what is needed for immediate use should be poured out at a time. This bottle should be kept covered with a paper cap or an inverted tumbler as long as there is milk in it.

New milk should never be mixed with old unless it is to be used at once; the old milk is likely to contain a larger proportion of bacteria. Some persons even go so far as to say that milk or cream that has been exposed to the air by being poured into other vessles for table or cooking use should not be poured into the general supply.

As soon as a milk bottle is empty, it should be rinsed first in cold water, and then in warm water until it appears clear; then set bottom up to drain. It should not be used for any other purpose than for milk.

All utensils with which milk comes in contact should be rinsed in cold water, washed, and scalded with water at or near the boiling

point every time they are used. It is a good plan to set them away unwiped. In no case should they be cleaned in water that has been used for other dishes since it was scalded.

The Application of Refrigeration to Milk.—The following data on the application of refrigeration for cooling and storing milk is taken from United States Department of Agriculture Bulletin No. 98:

Effect of Freezing on Milk.—While the action of cold on milk at a temperature above the freezing point has no other effect than that of varying the density and viscosity at a temperature below the freezing point, it changes the chemical and physical composition.

According to Kasdorf, when raw milk which was partly frozen at a temperature of 10.5° F., in the ordinary container, during transportation, it was found that ice first formed around the sides and at the bottom of the can; the central core contained most of the casein, sugar, and other mineral ingredients, while most of the fat was found in the top layer of the liquid portion.

When milk has been frozen gradually, without agitation, and thawed out, clots will be found floating in the liquid, composed mostly of albumen and fat, which may be dissolved by cooking; on the other hand, if the milk is preserved in a frozen condition for three or four weeks, these clots will be very hard to dissolve, and the difficulty experienced in dissolving them increased as the length of time the milk is preserved in a frozen state. For this reason, the freezing of milk, for the purpose of transportation, has hitherto been little used.

If the milk is held at 32° F., for a few days, some types of bacteria may grow and multiply slowly. With a good quality of milk, i. e., that containing few bacteria, it may take weeks or even months for them to gain great headway. What few bacteria develop at low temperatures are of different species from those ordinarily found at the higher temperatures, and they may produce marked changes in the chemical composition of the milk, without especially changing its appearance. Consequently, it is unsafe to assume that milk which has been held for several days at a low temperature is in good condition. According to Pennington, milk exposed continually to a temperature of 29° to 32° F., causes, after a lapse of from 7 to 21 days, the formation of small ice crystals which gradually increase until the milk is filled with them, and there may be an adherent layer on the walls of the vessel. The milk does not freeze solid. In spite of the fact that the milk was a semi-solid mass of ice crystals, an enormous increase in bacterial content took place. Though the bacterial content was numerically in the hundreds of millions per cubic centimeter there was neither taste nor odor to indicate that such was the case.

Neither did the milk curdle when heated, and the unfitness of the milk for household purposes would not ordinarily be detected until the lactic acid bacteria decreased in numbers and the putrefactive bacteria began to develop.

Influence of Temperature on the Bacteriological Flora of Milk.—Each species of bacterium found in milk and each particular variety has an upper and lower temperature limit beyond which it does not grow, and a certain temperature, called the optimum, at which it grows best.

The optimum temperature of most forms occurring in milk is between 70° and 100° F. As the temperature of milk is lowered, the rate of growth is diminished until at 40° F., the multiplication is very slow, and at a temperature just above the freezing point the development practically ceases; in fact, there is an apparent decrease in the number, at least for a short time. The action of cold at this temperature, however, does not totally destroy life in the bacteria, but causes them to lie dormant. When the temperature of the milk is raised, they again begin to multiply. As an illustration of the relative variation in the growth of bacteria in milk held at different temperatures, one writer gives the data found in Table XCII, in which "I" is assumed to represent the number of bacteria in the fresh milk, and the relative numbers which will be found at the end of 6, 12, 24, and 48 hours, at the two temperatures, are shown in the succeeding columns. The figures are based on a number of actual counts and illustrate the effect of a difference of 18 degrees on the multiplication of bacteria. If the milk had contained at the beginning 1,000 bacteria, the part held at the lower temperature would have contained at the end of 24 hours only 4,100 bacteria, while the other would have contained at the same stage 6,128,000. Table XCIII from Bulletin 133 (Extension Bulletin 8) of the Agricultural Experiment Station of Nebraska, illustrates the importance of holding cream at low temperatures.

TABLE XCII.—MULTIPLICATION OF BACTERIA IN MILK HELD AT DIFFERENT TEMPERATURES.

Milk Held at	Relative Number of Bacteria Held at 0 hrs.	6 hrs.	12 hrs.	24 hrs.	48 hrs.
50° F.	1	1.2	1.5	4.1	6.2
68° F.	1	1.7	24.2	6,128.	357,499.

Rogers, Lore A., Bacteria in Milk. U. S. Department of Agriculture, Farmers' Bulletin 490. Washington, D. C.

Influence of Time on the Bacteriological Flora of Milk.—The influence of temperature and time bear certain definite relations to each other; hence, a study of one necessarily includes a study of the other. Table XCIV serves to illustrate the effect of time as well as tem-

perature on the keeping qualities of milk. If the table is read downward, we note the effect of temperature and if read across, the effect of time. When milk is first drawn from the cow it usually contains bacteria, even though it is produced under sanitary conditions, and if held at the ordinary temperature of the surrounding air, in a short while the bacteria will grow and increase in numbers so rapidly, that when such milk reaches the consumer it will contain many thousand bacteria per cubic centimeter.

TABLE XCIII.—THE EFFECT OF TEMPERATURE ON THE GROWTH OF BACTERIA IN CREAM.

Temperature of Cream	Time Held	Number of Bacteria per C. C.	Temperature of Cream	Time Held	Number of Bacteria per C. C.
Degrees Fahr.	Hours		Degrees Fahr	Hours	
32	10	3,300	70	11	188,000
50	10	11,580	80	11	2,631,000
60	10½	15,120	90	11½	4,426,000

Conn furnishes an example of milk, giving the following results:

	Bacteria per c. c.
Milk drawn at 59° F.	153,000
After 1 hour	616,000
" 2 hours	539,000
" 4 hours	680,000
" 7 hours	1,020,000
" 9 hours	2,040,000
" 24 hours	85,000,000

According to Park, two samples of milk maintained at different temperatures for 24, 48, 96 and 168 hours, respectively, showed the development of bacteria as indicated in Table XCIV. The first sample was obtained under the best possible conditions, while the second sample was obtained in the usual way. When received, the first sample contained 3,000 bacteria, and the second 30,000 per cubic centimeter.

In Table XCIV, it will be noted that at 32° F., there is an actual decrease in the number of bacteria in both samples of milk during the 168 hours, while at all other temperatures there is an increase in the numbers of bacteria. Ordinarily, the consumer receives milk when it is from 24 to 48 hours old; hence, it becomes an easy matter to deliver the milk in good condition, providing the milk is produced under sanitary conditions and is properly cooled and held at a temperature of 50° F., or below. An examination of the tables and figures will show how intimately the two influences of time and temperature act and interact in relation to the multiplication of bacteria in milk.

From the foregoing, it is obvious that proper refrigeration is of the utmost importance in the preservation of milk. In fact, without thorough cooling, it is impracticable to keep milk for any considerable length of time, in a condition that would justify its use for household purposes. It should be cooled at 50° F. or below as quickly as possible after it is drawn from the cow, as such cooling will at once check the increase of bacteria.

TABLE XCIV.—EFFECT OF TIME AND TEMPERATURE ON THE GROWTH OF BACTERIA IN MILK.

Temperature	24 Hours	48 Hours	96 Hours	168 Hours
32° F. (0 C.)	2,400	2,100	1,850	1,400
	30,000	27,000	24,000	19,000
39° F. (4 C.)	2,500	3,600	218,000	4,200,000
	38,000	56,000	4,300,000	38,000,000
42° F. (5 C.)	2,600	3,600	400,000	
	43,000	210,000	5,760,000	
46° F. (6 C.)	3,100	12,000	1,480,000	
	42,000	360,000	12,200,000	
50° F. (10 C)	11,600	540,000		
	89,000	1,940,000		
55° F. (13 C.)	18,800	3,400,000		
	187,000	38,000,000		
60° F. (16 C.)	180,000	28,000,000		
	900,000	168,000,000		
68° F. (20 C.)	450,000	25,000,000,000		
	4,000,000	25,000,000,000		
86° F. (30 C.)	1,400,000,000			
	14,000,000,000			
94° F. (35 C.)	25,000,000,000			
	25,000,000,000			

Bacteria in Milk.—Farmers' Bulletin No. 1207 of the United States Department of Agriculture gives the following discussion on the development and growth of bacteria:

Besides the chemical compounds, milk also contains large numbers of minute organisms called bacteria. Few, if any, are normally present in the milk within the udders of clean, healthy cows, but they are so abundant everywhere in the air, especially about the stable and barnyard, and cling in such numbers to the bodies of the cows, that they are almost always found in milk as soon as it leaves the udders or even just inside the teats. Utensils that have not been sterilized are another very common source of bacteria in milk. Bacteria reproduce very rapidly in a favorable medium, such as warm milk, and the number present becomes very large unless measures are taken to hinder their increase. The amount in milk of a given age varies of course with the conditions.

A great many kinds of bacteria have been found in milk, each of which occasions a special set of changes as it develops. Perhaps the most prevalent kinds are those that cause the ordinary souring of milk and are the first to produce any noticable change in the taste and odor. In their growth they feed upon the milk sugar and convert it into lactic and volatile acids, which give slightly soured milk its peculiar taste and odor. When enough of this lactic acid has formed it acts upon the casein, causing it to separate into loose, light flakes and to form, upon standing, the ordinary "clabbered" milk. Other bacteria developing in sour milk may give it a strong, unpleasant odor or flavor, and still others, which occur occasionally color it very brightly or give it a slimy or ropy consistency. Some of the products of bacterial action on milk are desirable, however,—for instance, those that give to butter and cheese the characteristic flavors and odors.

Since there is frequently more or less dirt in freshly drawn milk (most of it fine particles of litter and manure that fall into the pail from the body of the cow), milk should always be strained directly after the milking is over. Of course, the amount of dirt varies with the condition in which the cow and her surroundings are kept. Under ideal dairy conditions only very small quantities are found, while milk from untidy establishments may contain enough in a quart to form a noticeable sediment. Milk with enough dirt to be visible indicates a badly kept dairy and should not be tolerated. Moreover, visible dirt does not tell the whole story; some of the manure that falls into milk is dissolved and it sometimes carries disease-producing bacteria. Consumers should always insist upon having clean milk, and they should also remember that cleanliness should not stop at the dairy but should be scrupulously maintained at every step of the way to the final consumption of the milk.

Ice Chests.—Mrs. Mary Hinman Abel, under the heading "Care of Food in the Home," gives the following considerations in reference to ice chests and refrigerators:

There are many varieties of ice chest or refrigerator, all built on one of two general plans. In one kind, both ice and food are kept in one large compartment. In the other, the ice is placed in a top compartment, below which are cupboards for the food; the principle here utilized is that cold air seeks a lower level and that the air cooled by the melting ice will sink to the shelves below. It probably better utilizes a given amount of ice, for the further reason that the ice compartment may remain tightly closed except when being filled. In both cases, the air space between the outside wall and the zinc lining is filled with some non-conducting material as cork or asbestos.

It is of great convenience to have the ice chest built against the outer wall of kitchen or pantry, so that it may be filled from the outside by means of a small door cut for that purpose. In such a case, it is of course advisable to choose a wall on which there is little or no sunshine. The ice box may also be drained by a pipe leading to the outside and then properly cared for, thus saving much labor in the emptying of pans. It is not considered safe to connect it with the house sewer, because of the danger of sewer gases backing into it, even if a good trap is provided.

Care of Ice Chests.—Farmers' Bulletin No. 375 of the United States Department of Agriculture gives the following instructions in reference to care of ice chests:

If on a warm summer day you put your hand into an ice box well filled with ice you may think that the temperature is very low, and yet it is in all probability nearer 50° than 40° F. As low a temperature as 40° or 45° is only to be obtained in a very well-constructed box with a large receptacle for ice, and then only for a short time after it is filled. A box that maintains but 60° is, however, very useful in keeping food from day to day.

The ice box, no matter how well cooled, is and must be damp, and dampness is one of the requirements for bacterial growth. It must be remembered, also, that some varieties of bacteria grow at low temperatures. Therefore, the interior of an ice chest should be wiped every day with a dry cloth and once a week everything should be removed, so that sides, shelves, and drain may be thoroughly scalded. The water must be actually boiling when it is poured in, and the process repeated several times.

It must be remembered that refrigerator ice is often dirty, and that it may bring in putrefactive or even typhoid bacilli, for most bacteria are resistant to low temperature and are not destroyed by freezing. On this account, no food should be brought in direct contact with it, nor should it be put into drinking water, unless its purity is above suspicion.

All cooked food should be cooled as soon as possible before being placed in the ice box. Butter may be kept from taking up the flavors of other food by keeping it in a tightly covered receptacle. Milk requires more access of air, but in a clean ice box in which no strong-smelling food is kept, milk should remain uninjured in flavor for twelve to twenty-four hours. If vegetables or other foods of pronounced odor are kept in glass jars with covers, or in covered earthenware receptacles, there will be a fewer odors to be communicated. Portions of canned food should never be put into the ice box in the tin cans. Such food does not of necessity develop a poisonous product, as has sometimes been claimed, but experiments show that

ptomaines are particularly liable to develop in such cases. Casting out this somewhat remote possibility, the "tinny" taste acquired by such keeping is enough to condemn the practice.

Foods that are to be eaten raw, such as lettuce and celery, should be carefully cleaned before being placed in the ice box, and may with advantage be wrapped in a clean, damp cloth. If they are to be kept for some days they should, however, be put in without removing the roots, the further precaution being taken to wrap them carefully in clean paper or to put them into grocers' bags.

Keeping of Vegetables, Fruits, and Meats.—The Farmers' Bulletin No. 375 of the United States Department of Agriculture gives some additional considerations in reference to the keeping of vegetables, fruits, and meats in the home. These are as follows:

The following hints regarding the keeping of different kinds of food may be found useful:

Potatoes are kept without difficulty in a cool, dry, and dark place. Sprouts should not be allowed to grow in the spring.

Such roots as carrots, parsnips, and turnips remain plump and fresh if placed in earth or sand filled boxes on the cellar floor.

Sweet potatoes may be kept until January if cleaned, dried, and packed in chaff so that they will not touch each other.

Pumpkins and squash must be thoroughly ripe and mature to keep well. They should be dried from time to time with a cloth and kept not on the cellar floor, but on a shelf, and well separated from each other.

Cabbages are to be placed in barrels, with the roots uppermost.

Celery should be neither trimmed nor washed, but packed, heads up, in long, deep boxes, which should then be filled with dry earth.

Tomatoes may be kept until January, if gathered just before frost, wiped dry, and placed on straw-covered racks in the cellar. They should be firm and well-grown speciments, not yet beginning to turn. As they ripen they may be taken out for table use, and any soft or decaying ones must be removed.

Apples, for use during the autumn, may be stored in barrels without further precaution than to look them over now and then to remove decaying ones; but if they are to be kept till late winter or spring they must be of a variety known to keep well and they must be hand-picked and without blemish or bruise. They should be wiped dry and placed with little crowding on shelves in the cellar. As a further precaution they may be wrapped separately in soft paper.

Pears may be kept for a limited time in the same way, or packed in sawdust or chaff; which absorbs the moisture which might otherwise favor molding.

Oranges and lemons are kept in the same way. Wrapping in soft paper is here essential, as the uncovered skins if bruised offer good feeding ground for mold. Oranges may be kept for a long time in good condition if stored where it is very cold, but where freezing is not possible. Lemons and limes are often kept in brine, an old-fashioned household method.

Cranberries, after careful looking over to remove soft ones, are placed in a crock or firkin and covered with water. A plate or round board placed on top and weighted serves to keep the berries under water. The water should be changed once a month.

In winter, large pieces of fresh meat may be purchased and hung in the cellar. Thin pieces, as mutton chops, are sometimes dipped in mutton suet, which keeps the surface from drying and is easily scraped off before cooking.

Turkeys, chickens, and other birds should be carefully drawn as soon as killed and without washing hung in the coolest available place.

Smoked ham, tongue, beef, and fish are best put in linen bags and hung in the cellar.

Salt pork and corned beef should be kept in brine in suitable jars, kegs, or casks, and should be weighted so as to remain well covered. A plate or board weighted with a clean stone is an old-fashioned and satisfactory device.

Eggs may be packed for winter use in limewater or in water-glass solution, methods which are described in an earlier bulletin of this series. Many housekeepers have good success in packing them in bran, in oats, or in dry salt, but according to experiments summarized in the aforementioned bulletin, the preference is to be given to the 10 per cent solution of water-glass. Exclusion of the air with its accompanying microorganisms and the prevention of drying out are what is sought in all cases. Packed eggs are not equal to fresh eggs in flavor, but when they are well packed are of fairly good quality and perfectly wholesome.

Apples.—The United States Department of Agriculture, in Farmers' Bulletin No. 1160, gives the following information in reference to the keeping of apples:

Apples will stand a temperature several degrees below freezing (32° F.). The danger point is at about 28° F. The effect of freezing is to cause brown spots which extend to the surface and are easily seen. These spots may appear on any part of the apple, but usually occur at places where the water content is highest. Freezing has about the same effect on either green or ripe fruit. Slightly frozen apples may be thawed out slowly without injury except to the quality. Apples should be packed in barrels, allowing good ventilation when stored for long periods. Some of the common diseases of apples are: Scab, blotch, fruit spot, Jonathan spot, bitter pit, drought spot, stig-

nonose, water core, bitter, anthracnose, black rot, altervaria rot, blue mold, pink rot, spongy dry rot, brown rot, gray mold, soft scald, and scald.

Drinking Water.—The desirable temperature for drinking water is 45° to 50° F. Tests have proven that at this temperature it is a mild heart stimulant and slightly reduces the internal temperature of the body. When drinking water colder than 45° F. is used there is danger of cramps.

The amount of drinking water required in industrial plants is usually considered to be approximately ¼ gallon per man per working hour. This amount is based on using fountains and includes the waste.

The amount of refrigeration required to cool drinking water varies from 0.0003 to 0.0005 tons refrigeration per hour per man.

Fig. 217 shows the refrigerating effect due to placing one, two, and three cubes of ice in a glass of drinking water. The weight of the water in the glass was 0.4 lbs.; the weight of the ice cube was 0.1 lb.; the size of the glass was three inches in diameter at the top, 2.3 inches in diameter at the bottom and five inches high; the room temperature was 75°, and the glass was placed on a wooden table. Inasmuch as 50° is the desirable temperature for the water, it will be observed that this temperature is practically obtained by the use of two cubes of ice per glass of water. It is further noted from Fig. 134, that the use of three cubes of ice, maintained the temperature of the water at a fairly low temperature at a considerable length of time, and that one cube does not produce the desirable refrigerating effect.

Specific and Latent Heat of Foods.—Table XCV gives the specific heats and latent heats of some of the common foods. The second column gives the specific heat of the foods before freezing, expressed in B.t.u. per lb., while the third column gives the corresponding specific heat after freezing. The latent heat of fusion which is liberated during the freezing process is given in the last column of this table.

Ice Cream Making in the Home.—The National Association of Ice Industries has recently published a small bulletin

entitled "Ice Cream Making and Appliances in the Home," which was prepared by M. A. Pennington, director of Household Bureau. The following extract on the subject of "Ice Cream Making in the Home" is taken from that bulletin:

The most satisfactory temperatures for the freezing of ice cream range from about 16° F. to about 6° F. These temperatures are ob-

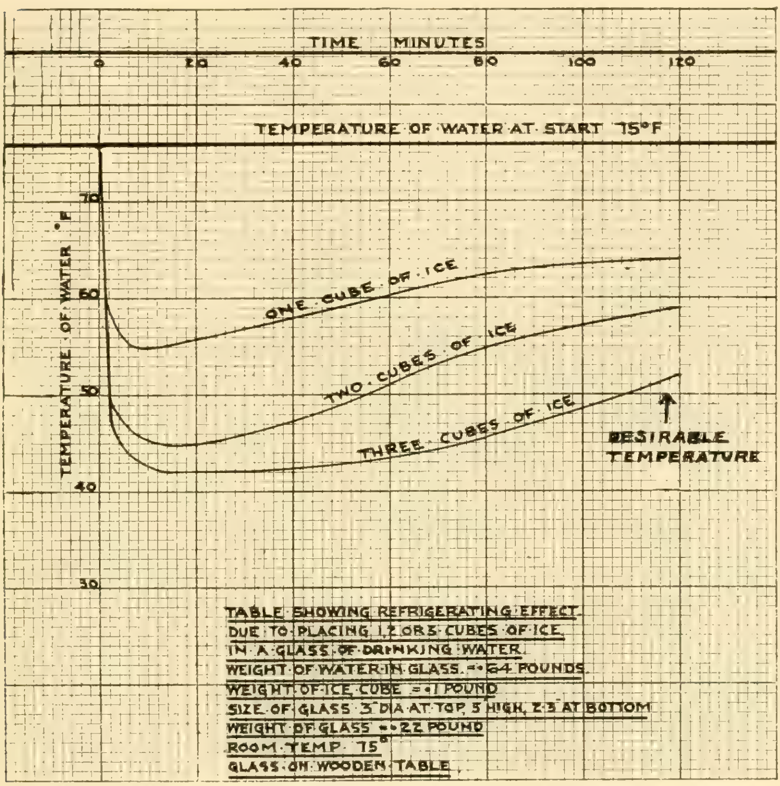

FIG. 217.—REFRIGERATING EFFECT OF ICE IN DRINKING WATER.

tained by the use of from 12 to 17 per cent of salt by weight, which is from 12 to 1 to 8 to 1 parts by volume. For uniformly good results, the ice and salt must be really measured, not just dumped in.

A great variety of flavors and ingredients can go into the making of ice creams and ices. Very palatable and nourishing "creams" can be made from very inexpensive materials. Again, however, proportions must be exact and directions must be followed.

The ice cream freezers on the market would seem to be sufficiently varied in capacity, operation, and price, to fill the need of

most individuals. The woman with the longer pocket-book can make the electric current do the churning for her. By substituting for the extra money outlay, exact attention to small details of manipulation

TABLE XCV.—SPECIFIC AND LATENT HEATS OF FOODS.

Article	Specific Heat		Latent Heat
	Before Freezing	After Freezing	
Apples	.92	......	......
Beans (green)	.91	......	......
Beef (fresh)	.75	.40	100
Beef (salt)	.60	......	......
Beer	.90	......	......
Berries	.91	......	......
Butter	.60	.84	84
Cabbage	.93	.48	129
Cantaloupes	.92	......	......
Carrots	.87	.45	118
Cherries (fresh)	.92	......	......
Cherries (dried)	.84	......	......
Cheese	.64	......	......
Chicken	.80	.42	105
Celery	.91	......	......
Cider	.90	......	......
Cream	.68	.38	84
Dates	.84	......	......
Eggs	.76	.40	100
Eels	.69	.38	88
Fish (fresh)	.80	.42	100
Fish (dried)	.58	......	......
Fruits (dried)	.89	......	......
Game	.80	.40	105
Grapes	.92	......	......
Grape Fruit	.92	......	......
Ice Cream	.78	.42	80
Lemons	.92	......	......
Lobster	.81	.42	108
Milk	.90	.47	124
Mutton	.67	.81	......
Onions	.91	......	......
Oranges	.92	......	......
Oysters	.84	.44	114
Peaches	.92	......	......
Pears	.92	......	......

TABLE XCV.—SPECIFIC AND LATENT HEATS OF FOODS.—(Continued).

Article	Specific Heat		Latent Heat
	Before Freezing	After Freezing	
Pigeon	.78	.41	102
Pork (fresh)	.50	.30	70
Potatoes	.80	.42	105
Poultry	.80	.40	102
Sausage	.70	-----	-----
Sausage (smoked)	.60	-----	-----
Strawberries	.92	-----	-----
Veal	.70	.39	90
Watermelons	.92	-----	-----
Wines	.90	-----	-----

and using mixtures, comparatively rich in cream, the crankless type of freezer can be made to produce excellent results. The athletic woman, who doesn't mind turning a crank nor shifting a staunchly made tub around, can get a freezer that will withstand hard knocks and long wear and tear; while the kitchenette apartment woman can buy a little, light appliance, that takes almost no room and is so inexpensive that she can leave it behind when she moves without qualm of conscience. First of all, the woman must understand her own problem well enough to make an intelligent selection. Such understanding can only come from a knowledge of the facts of the case.

Food Arrangement in Refrigerators.—Fig. 218 shows one of the suggested arrangements of food in household refrigerators. From this, it will be noted that the foods are stored with reference to two considerations. In the first place, special consideration is given to the temperature in different parts of the refrigerator. Those foods requiring the lowest temperatures are placed immediately under the ice compartment, and in the bottom part of the refrigerator, while those which require a higher temperature are placed in the top food compartment. A second consideration is the storing of foods which give off characteristic odors. Foods such as onions, lemons, cabbage, cheese, etc., are placed in the uppermost food compartment, so that the air in passing directly into the ice chamber from this food compartment, carries with it the odor from such foods. Thus the air allows part of the odors to be condensed and eliminated.

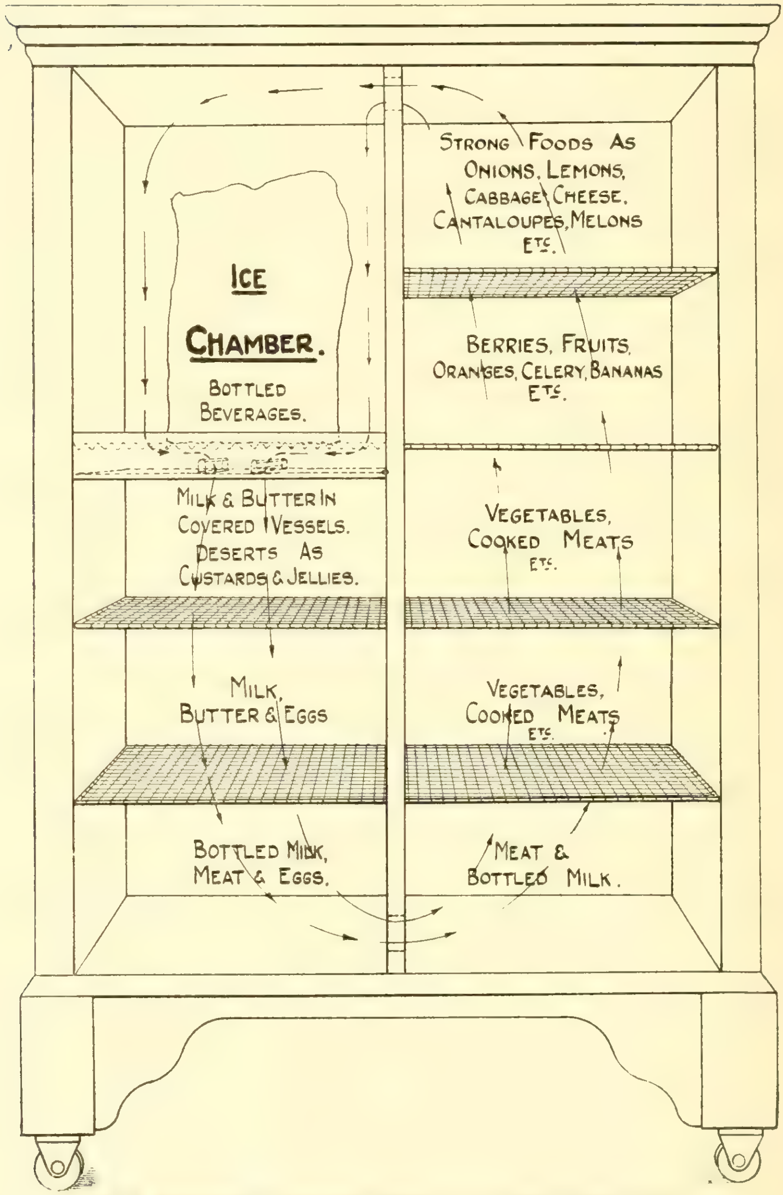

FIG. 218.—FOOD ARRANGEMENT IN REFRIGERATORS.

CHAPTER XIII.

MISCELLANEOUS TABLES.

Miscellaneous Tables.—The following miscellaneous tables may be classified into two divisions. In the first division are those tables which are especially related to the design, construction, and operation of both ice and mechanically cooled household refrigerators. In the second division are those which are only indirectly related to the subject of "Household Refrigeration." They pertain mostly to physics and mechanics.

Table XCVI gives some summer temperatures for the different states in the United States. The second column gives the average summer temperature in degrees F., while the third column gives the maximum temperature in degrees F. Some temperatures by months in various cities of France are given in Table XCVII. The temperatures in this table are degrees Centigrade. The average annual humidities for various cities in the United States are shown by Table XCVIII. Table XCVIX shows average summer and yearly tap water temperatures for a number of cities.

Table C gives the domestic water rates for a number of cities in the United States. This table includes the population of the various cities, the highest domestic rate per gallon of water, and the minimum annual water charge.

Table CI gives some average figures for the household consumption of water per year for a number of cities. It will be noted that the average consumption of water for the cities stated per household is 6369 cubic feet. This is equivalent to 17.5 cubic feet per day or 131 gallons per day.

TABLE XCVI.—SUMMER TEMPERATURES IN THE UNITED STATES.
(U. S. Weather Reports.)

State	Average Summer Temp. Deg. F.	Maximum Summer Temp. Deg. F.
Arizona	92	120
Oklahoma	83	114
Texas	83	112
Louisiana	83	110
Arkansas	83	106
Georgia	82	108
Connecticut	82	106
Delaware	82	102
North Carolina	81	109
South Carolina	81	109
Florida	81	109
Alabama	81	105
Mississippi	81	105
Missouri	80	113
Tennessee	80	107
Kansas	79	116
Nevada	79	110
Maryland	79	106
Utah	79	106
New Mexico	79	105
Iowa	78	111
Kentucky	78	97
California	77	117
Virginia	76	104
Nebraska	75	112
West Virginia	75	102
Pennsylvania	74	105
Colorado	73	106
Ohio	73	105
Indiana	73	104
Illinois	73	102
New Jersey	73	102
Washington	71	114
New York	71	104
Michigan	71	104
Massachusetts	70	105
New Hampshire	70	105
Wisconsin	70	103
Wyoming	69	108
Rhode Island	69	99
Maine	68	105
Montana	67	106
North Dakota	67	102
South Dakota	67	102
Vermont	65	102
Minnesota	63	102
Idaho	63	94
Oregon	62	99

Table CII gives the quantities of water which are discharged by house service pipes in gallons per minute. This table is for various diameters of pipes, with certain initial water pressures, no back pressure, and through 100 feet of service pipe.

Table CIII gives the list of cities which use electric current different from the standard alternating current, 60 cycles and 110 or 220 volts.

TABLE CXVII.—TEMPERATURES BY MONTHS IN FRANCE.
(1912-1917 Inclusive.)

	Angers Degrees C.	Auxerre Degrees C.	Bordeaux Degrees C.	Chaumont Degrees C.
January	4.	2.	5.	0.5
February	5.	4.	6.	2.
March	7.	6.	8.5	5.
April	10.5	10.5	11.5	9.5
May	14.	13.	14.5	13.
June	17.	18.	17.5	16.5
July	19.	19.5	20.	18.5
August	19.	19.	20.	18.
September	15.5	15.5	17.5	14.5
October	11.	10.5	13.	9.5
November	7.	6.	8.5	5.
December	4.	2.	5.	1.1
Average	11.0	10.5	12.0	9.5

From French Government Weather Reports.

Summer and Winter Tap Water Temperatures.—Table C shows the relative importance of tap water temperature and density of population in the important cities of United States and Canada.

It is readily seen that the summer water temperatures are mostly under 75° F., while 80° includes nearly all of the important cities.

In winter 65° is the maximum temperature reached in nearly all of the larger cities.

In some parts of Texas summer tap water temperatures as high as 120° are reported.

TABLE XCVIII.—RELATIVE HUMIDITIES IN VARIOUS CITIES.
(U. S. Weather Reports.)

Average Annual Humidities for Various Cities of United States.		
City	8 a. m.	8 p. m.
Albany, N. Y.	78	72
Asheville, N. C.	85	71
Atlanta, Ga.	79	65
Atlantic City, N. J.	80	79
Augusta, Ga.	82	66
Baltimore, Md.	72	66
Boston, Mass.	73	70
Hartford, Conn.	74	68
Jacksonville, Fla.	83	77
Key West, Fla.	78	77
Macon, Ga.	83	....
New Haven, Conn.	75	72
New York, N. Y.	75	62
Norfolk, Va.	80	75
Philadelphia, Pa.	74	66
Portland, Me.	75	73
Providence, R. I.	74	71
Savannah, Ga.	81	75
Washington, D. C.	76	68
Wilmington, N. C.	81	77
Birmingham, Ala.	79	65
Galveston, Texas	84	78
Mobile, Ala.	84	74
Montgomery, Ala.	82	64
New Orleans, La.	83	72
Pensacola, Fla.	80	75
San Antonio, Texas	81	53
Tampa, Fla	84	76
Buffalo, N. Y.	77	73
Chattanooga, Tenn.	80	63
Chicago, Ill.	78	71
Cincinnati, Ohio	76	62
Cleveland, Ohio	77	70
Columbus, Ohio	79	66
Detroit, Mich.	80	71
Duluth, Minn.	81	71
Grand Rapids, Mich.	82	70
Indianapolis, Ind.	77	64
Louisville, Ky.	76	61
Dayton, Ohio	80	67
Milwaukee, Wis.	78	72
Nashville, Tenn.	80	62
Pittsburgh, Pa.	77	66
Rochester, N. Y.	75	71
Syracuse, N. Y.	77	....
Toledo, Ohio	79	69
Davenport, Iowa	80	65
Des Moines, Iowa	80	63
Kansas City, Mo.	77	62
Memphis, Tenn.	79	65
St. Louis, Mo.	77	63
St. Paul, Minn.	80	63
Springfield, Ill.	79	65

TABLE XCVIII.—RELATIVE HUMIDITIES IN VARIOUS CITIES.
(U. S. Weather Reports.)—(Continued).

Average Annual Humidities for Various Cities of United States.

City	8 a. m.	8 p. m.
Fort Worth, Texas	78	....
Lincoln, Neb.	79	59
Oklahoma City, Okla.	80	59
Omaha, Neb.	78	60
Sioux City, Iowa	81	61
Wichita, Kan.	78	57
Denver, Colo.	63	41
El Paso, Texas	54	26
Helena, Mont.	68	50
Phoenix, Ariz.	54	28
Pueblo, Colo.	64	37
Reno, Nev.	72	39
Salt Lake City, Utah	60	45
Santa Fe, N. Mex.	58	40
Spokane, Wash.	77	50
Los Angeles, Cal.	78	62
Portland, Ore.	86	63
Sacramento, Cal.	82	52
San Diego, Cal.	79	70
San Francisco, Cal.	87	72
Seattle, Wash.	87	67

TABLE XCIX.—TAP WATER TEMPERATURES.

City	Average Summer Temp. Deg. F.	Average Yearly Temp. Deg. F.
Augusta, Ga.	81	66
Atlanta, Ga.	81	62
Albany, N. Y.	76	56
Allentown, Pa.	60	57
Akron, Ohio	74	55
Birmingham, Ala.	80	65
Buffalo, N. Y.	71	52
Boston, Mass.	69	54
Columbus, Ohio	74	56
Charleston, W. Va.	70	40
Cleveland, Ohio	72	56
Cincinnati, Ohio	80	62
Cambridge, Mass.	70	50
Cedar Rapids, Iowa	68	55
Dayton, Ohio	70	60
Detroit, Mich.	67	50
Davenport, Iowa	....	56
Duluth, Minn.	55	45
Des Moines, Iowa	65	58
Decatur, Ill.	73	53
Erie, Pa.	70	53
East Orange, N. J.	58	58
Elizabeth, N. J.	60	50
Fort Wayne, Ind.	....	50
Gary, Ind.	62	52

TABLE XCIX.—TAP WATER TEMPERATURES.—(Continued).

City	Average Summer Temp. Deg. F.	Average Yearly Temp. Deg. F.
Grand Rapids, Mich.	74	55
Galveston, Texas	85	80
Hamilton, Canada	55	43
Haverhill, Mass.	58	40.7
Johnstown, Pa.	65	50
Jackson, Miss.	65	45
Jacksonville, Fla.	82	76
Kansas City, Kan.	77	62
Lincoln, Neb.	60	55
Louisville, Ky.	70	60
Little Rock, Ark.	70	50
Los Angeles, Cal.	62	60
Lowell, Mass.	56	54
Lexington, Ky.	67.8	57.4
Lawrence, Mass.	60	55
Milwaukee, Wis.	52	50
Montreal, Ont., Can.	67	51
Minneapolis, Minn.	72	54
Mt. Vernon, N. Y.	73	55
Malden, Mass.	69	54
Mobile, Ala.	70	60
New Brunswick, N. J.	60	57
New York, N. Y.	65	55
New Haven, Conn.	65	58
Nashville, Tenn.	75	60
New Orleans, La.	80	65
New Bedford, Mass.	69	55
Oklahoma City, Okla.	75	60
Ottawa, Ont., Can.	77	54
Omaha, Neb.	86	60
Oakland, Cal.	70	55
Providence, R. I.	74	53
Portland, Maine	70	50
Patterson, N. J.	60	50
Pawtucket, R. I.	72	55
Pittsburgh, Pa.	72.5	52.8
Portland, Ore.	50	42
Pasadena, Cal.	63	57
Roanoke, Va.	60	60
Rochester, N. Y.	69	51
Richmond, Va.	74	70
Rockford, Ill.	58	58
Springfield, Mass.	64	49
Superior, Wis.	60	47
Springfield, Mo.	65	60
Spokane, Wash.	52	50
Salt Lake City, Utah	50	45
Sommerville, Mass.	69	53.5
Springfield, Ohio	58	57
St. Joseph, Mo.	77	54
St. Paul, Minn.	65	54
Sioux City, Iowa	51	49
St. John, N. B.	65	51
San Francisco, Cal.	65	57

TABLE XCIX.—TAP WATER TEMPERATURES.—(Continued).

City	Average Summer Temp. Deg. F.	Average Yearly Temp. Deg. F.
Seattle, Wash.	55	49
Toledo, Ohio	76.4	56
Terre Haute, Ind.	76	57
Tacoma, Wash.	60	40.5
Troy, N. Y.	70	60
Utica, N. Y.	68	55
Waterbury, Conn.	71	54
Winnipeg, Man., Can.	70	56
Woonsocket, R. I.	70	50
Worcester, Mass.	72	68
Washington, D. C.	75.4	60.5
Youngstown, Ohio	90.8	68.7

TABLE C.—DOMESTIC WATER RATES.
(*American City Magazine.*)

City	Population	Highest Domestic Rate per 1,000 Gal.	Minimum Annual Charge
Mobile, Ala.	69,151	15c	6.00
Montgomery	43,464	15c	12.00
Los Angeles, Cal.	578,000	13.3c	9.00
San Diego	74,683	14.7c	
Stockton	40,296	25c	12.00
Colorado Springs, Colo.	30,105	15c	12.00
Bridgeport, Conn.	143,538	18c	10.00
Hartford	138,036	16c	5.00
Meriden	29,842	15c	7.50
New Britain	59,316	10c	5.00
Norwich	29,685	26.7c	5.00
Stamford	35,086	20c	6.00
Wilmington, Del.	110,168	10c	10.00
Washington, D. C.	437,571	10c	5.65
Miami, Fla.	29,549	20c	12.00
Atlanta, Ga.	200,616	13.3c	9.60
Augusta	52,548	25c	9.00
Savannah	83,252	12c	....
Honolulu, Hawaii	83,327	10c	6.00
Boise, Idaho	28,000	27c	12.00
Bloomington, Ill.	28,725	35c	3.25
Cicero	44,995	13.3c	6.00
Decatur	43,818	8c	4.00
Evanston	37,215	6.8c	6.00

TABLE C.—DOMESTIC WATER RATES.—(Continued).
(*American City Magazine.*)

City	Population	Highest Domestic Rate per 1,000 Gal.	Minimum Annual Charge
Peoria	76,121	30c	3.20
Quincy	35,978	50c	10.00
Rock Island	35,177	18.7c	8.10
Evansville, Ind.	85,549	20c	2.00
Fort Wayne	86,549	16c	6.00
Richmond	26,765	20c	6.00
South Bend	70,983	12c	7.20
Terre Haute	66,083	25c	9.00
Cedar Rapids, Iowa	45,566	25.3c	9.00
Council Bluffs	36,162	35c	6.00
Des Moines	126,468	30c	4.00
Sioux City	71,227	25c	None
Topeka, Kan.	50,022	45c	4.80
Covington, Ky.	57,121	24c	8.00
Lexington	41,534	25c	6.00
Louisville	234,891	40c	12.00
New Orleans, La.	387,408	10c	3.00
Shreveport	43,874	25c	7.80
Bangor, Maine	25,978	33.3c	12.00
Biddeford	28,000	26.7c	16.00
Baltimore, Md.	738,826	8.7c	
Cumberland	29,837	7c	8.00
Hagerstown	28,066	30c	6.00
Hyattsville	50,000	12c	4.00
Brookline, Mass.	37,748	16c	None
Brockton	66,138	25.3c	
Cambridge	109,694	10c	5.00
Chelsea	43,184	14.7c	6.00
Chicopee	36,214	20c	10.00
Everett	40,120	16.7c	6.00
Fall River	120,485	28c	None
Fitchburg	41,013	24c	5.00
Haverhill	53,884	21.3c	10.00
Lawrence	94,270	24c	8.00
Lowell	112,759	28c	10.50
Lynn	99,148	20c	10.00
New Bedford	121,217	15c	5.00
Quincy	47,876	33c	8.00
Revere	28,823	20c	10.00
Salem	42,529	20c	3.00
Somerville	93,091	16c	6.00
Springfield	129,563	30c	None
Taunton	37,137	25c	6.00
Waltham	30,915	27c	5.00
Worcester	179,754	20c	4.00

TABLE C.—DOMESTIC WATER RATES.—(Continued).
(*American City Magazine.*)

City	Population	Highest Domestic Rate per 1,000 Gal.	Minimum Annual Charge
Battle Creek, Mich.	36,164	13c	3.00
Bay City	47,554	10c	6.00
Highland Park	46,499	70c	5.00
Jackson	48,374	13.3c	3.20
Lansing	57,327	16c	7.80
Saginaw	61,903	11c	10.00
Duluth, Minn.	98,917	20c	6.00
Minneapolis	380,498	8c	
St. Paul	234,595	8c	3.60
Joplin, Mo.	29,855	35c	12.00
Lincoln, Neb.	54,934	15c	6.00
Manchester, N. H.	78,384	13.3c	8.00
Nashua	28,379	24c	16.00
Belmar, N. J.	25,000	23.3c	10.50
Camden	116,309	25c	8.00
Jersey City	279,864	12c	None
Kearney	26,724	20c	6.76
Montclair	28,810	30c	10.00
Newark	414,216	13.3c	6.00
New Brunswick	32,779	20c	15.00
Paterson	135,866	30c	12.00
Albany, N. Y.	113,344	13.3c	
Binghamton	66,800	10c	4.00
Buffalo	506,775	8c	10.00
Elmira	45,305	40c	6.00
Jamestown	38,917	20c	6.00
Kingston	26,688	22.2c	14.00
Mt. Vernon	42,726	40c	12.00
New York City	5,621,151	13.4c	None
N. Y. C. Brooklyn	2,022,262	13.3c	
N. Y. C. Queens	172,775	.	
N. Y. C. Richmond	115,959	13.3c	None
Niagara Falls	50,760	8c	6.00
Poughkeepsie	35,000	26.7c	1.00
Rochester	295,750	14c	4.00
Rome	26,341	20c	5.00
Schenectady	88,723	7c	3.00
Syracuse	171,717	14.8c	4.00
Troy	72,013		
Utica	94,156	40c	
Yonkers	100,226	21.3c	8.00
Charlotte, N. C.	46,338	26c	6.00
Wilmington	33,372	21.6c	13.00
Akron, Ohio	208,435		
Cincinnati	410,247	16c	4.80

TABLE C.—DOMESTIC WATER RATES.—(Continued).
(*American City Magazine.*)

City	Population	Highest Domestic Rate per 1,000 Gal.	Minimum Annual Charge
Cleveland	796,836	5.3c	2.50
Columbus	237,031	16c	4.00
Dayton	152,559	12c	6.60
Lakewood	41,732	12c	5.40
Lorain	37,295	2.00	8.00
Mansfield	27,824	26.7c	6.00
Newark	26,718	24c	6.00
Springfield	60,840	10c	4.00
Steubenville	28,508	40c	5.00
Toledo	243,109	13.3c	8.50
Youngstown	132,358	26.7c	None
Zanesville	29,569	15c	6.00
Oklahoma City, Okla.	91,258	32c	7.00
Tulsa	72,075	25c	9.00
Portland, Ore.	258,288	10.7c	6.00
Allentown, Pa.	73,502	106.70	.72
Chester	58,030	34.5c	6.96
Harrisburg	75,917	5.7c	4.00
Johnston	67,327	27c	12.00
Philadelphia	1,823,158	13.3c	
Pittsburgh	588,193	18c	8.00
Newport, R. I.	30,255	40c	
Providence	237,595	20c	8.00
Charleston, S. C.	67,957	24.7c	12.00
Sioux Falls, S. D.	25,176	40c	9.00
Knoxville, Tenn.	77,818	18c	10.08
Memphis	162,351	33.3c	12.00
Nashville	118,342	17.7c	6.00
Austin, Texas	34,876	20c	6.00
Dallas	158,977	25c	
El Paso	77,543	27.5c	15.00
Fort Worth	106,482	60c	13.80
Galveston	44,255	26.7c	3.00
Waco	38,500	37.5c	9.00
Salt Lake City, Utah	118,110	7.3c	6.00
Danville, Va.	25,000	10c	6.00
Lynchburg	29,956	28.8c	
Richmond	171,667	13.5c	7.20
Bellingham, Wash.	25,570	23.3c	12.00
Seattle	315,652	13.3c	6.00
Spokane	104,437	10c	9.60
Tacoma	96,965	13.3c	6.00

TABLE C.—DOMESTIC WATER RATES.—(Continued).

City	Population	Highest Domestic Rate per 1,000 Gal.	Minimum Annual Charge
Charleston, W. Va.	39,608	30c	12.00
Clarksburg	27,869	35c	9.00
Huntington	50,177	20c	9.00
Wheeling	54,322	15c	
Kenosha, Wis.	40,472	16c	6.00
La Crosse	30,363	20c	
Madison	38,378	10c	4.00
Milwaukee	457,147	8c	None
St. John, New Brunswick	60,000	None	12.00
Sydney, Nova Scotia	27,000	25c	8.00
Brantford, Ontario	32,700	35c	4.00
London	60,000	16.8c	8.00
Ottawa	112,000		
Toronto	499,278	13.8c	
Montreal, Quebec	694,000	12.8c	
Quebec	120,000	60c	

TABLE CI.—AVERAGE HOUSEHOLD CONSUMPTION OF WATER.

City	Cubic Feet Per Year
Boston, Mass.	6,000
Cincinnati, Ohio	6,000
Cleveland, Ohio	9,000
Dayton, Ohio	3,600
Flint, Mich.	7,200
Grand Rapids, Mich.	8,000
Milwaukee, Wis.	5,300
Peoria, Ill.	6,400
Pontiac, Mich.	8,000
Richmond, Ky.	2,400
Rockford, Ill.	8,400

Average: 6,391 cubic feet yearly, 17.5 cubic feet per day, 131 gallons per day.

TABLE CII.—QUANTITY OF WATER DISCHARGED FROM HOUSE SERVICE PIPES IN GALLONS PER MINUTE.

Through 100 Ft. of Service Pipe, No Back Pressure.

Pressure in Main Lbs. per sq. in.	Nominal Diameter of Pipes in Inches.					
	½	⅝	¾	1	1½	2
30	4.94	8.65	13.8	28.2	77.7	15.9
40	5.76	10.0	15.8	32.6	90.0	184.
50	6.44	11.2	17.7	36.4	100.5	206.
60	7.04	12.3	19.4	39.9	110.	225.
75	7.85	13.8	21.7	44.6	123.	252.
100	9.12	15.9	25.1	51.6	142.	291.
130	10.4	18.1	28.6	58.8	162.	352.

TABLE CIII.—CITIES USING ELECTRIC CURRENT DIFFERENT FROM THE STANDARD A. C. 60 CYCLES, 110-220 VOLTS.

(Cities of 50,000 population or over.)

Location.	D. C.	A. C.	Cycles	Volts
Mobile, Ala.	x	x	60	118
Little Rock, Ark.	x	x	60	110
Los Angeles, Cal	x	x	50	110-220-440
Pasadena, Cal.		x	50	115
Glendale, Cal.		x	50	110-220
Canon City, Colo.		x	30	120
Denver, Colo.	x	x	60	110
Bridgeport, Conn.	x	x	60	110
Hartford, Conn.	x	x	60	110-220
Wilmington, Del.	x	x	60	110-115
Atlanta, Ga.		x	25 & 60	110-220
Savannah, Ga.	x	x	60	110
Chicago, Ill.	x	x	60	115
Alton, Ill.		x	25	110
Indianapolis, Ind.	x	x	60	118
Richmond, Ind.	x	x	60	116 A. C. & 500 D. C.
Des Moines, Iowa	x	x	60	115-230
Sioux City, Iowa	x			104
Topeka, Kan.	x	x	60	115
New Orleans, La.	x	x	60	110-220
Portland, Maine	x	x	60	116
Baltimore, Md.	x	x	60	120
Boston, Mass.	x	x	60	113
Detroit, Mich.	x	x	60	120 & 240
Crookston, Minn.	x	x	60	110
Kansas City, Mo.	x	x	60 & 25	110 & 220
Kearney, Neb.		x	60	125
Portsmouth, N. H.		x	60 & 25	117
New Egypt, N. J.	x			220
Albany, N. Y.		x	40	115
Borough of Brooklyn	x	x	25 & 62.5	120
Borough of Manhattan	x	x	60	110 A. C. & 120 D. C.
Niagara Falls, N. Y.		x	25	110
Rochester, N. Y.	x	x	60 & 25	117
Syracuse, N. Y.		x	25 & 60	110
Spray, N. C.	x			220
Cincinnati, Ohio	x	x	60	118
Toledo, Ohio	x	x	60 & 25	110
Portland, Ore.	x	x		120-240
Altoona, Pa.	x	x	60	110
Philadelphia, Pa.	x	x	60	110
Scranton, Pa.	x	x	60	115
Columbia, S. C.		x	40	115
Dallas, Texas	x	x	60	110-220
Galveston, Texas	x	x	60	110
Rutland, Vermont		x	25 & 60	115
Norfolk, Va.	x	x	60	112
Milwaukee, Wis.	x	x	25 & 60	120-240
Laramie, Wyo.	x	x	60	110
Brandon, Canada	x	x	60	120
Hamilton, Ontario, Can.		x	66⅔	110-220
Stratford, Ont.		x	25	110-220
Toronto, Ont.		x	25	115

TABLE CIII.—CITIES USING ELECTRIC CURRENT DIFFERENT FROM THE STANDARD A. C. 60 CYCLES, 110-220 VOLTS.—(Continued.)

(Cities of 50,000 population or over.)

Location.	D. C.	A. C.	Cycles	Volts
Quebec		x	64	104
Guadalajara, Mexico		x	100	104-1040
Victoria, Mexico		x	125	104
Mexico, Mexico			50	210-3000
Barbados, West Indies		x	50	210
Havana	x		62½	110
Santo Domingo		x	133	104
Georgetown, British Guiana		x	125	104

TABLE CIV.—TEMPERATURE CONVERSION CENTIGRADE TO FAHRENHEIT.

C.	F.	R.	C.	F.	R.	C.	F.	R.
+100°	+212.0°	+80.0°	+53°	+127.4°	+42.4°	+ 6°	+42.8°	+4.8°
99	210.2	79.2	52	125.6	41.6	5	41.0	4.0
98	208.4	78.4	51	123.8	40.8	4	39.2	3.2
97	206.6	77.6	50	122.0	40.0	3	37.4	2.4
96	204.8	76.8	49	120.2	39.2	2	35.6	1.6
95	203.0	76.0	48	118.4	38.4	1	33.8	0.8
94	201.2	75.2	47	116.6	37.6	Zero	32.0	Zero
93	199.4	74.4	46	114.8	36.8	− 1	30.2	− 0.8
92	197.6	73.6	45	113.0	36.0	2	28.4	1.6
91	195.8	72.8	44	111.2	35.2	3	26.6	2.4
90	194.0	72.0	43	109.4	34.4	4	24.8	3.2
89	192.2	71.2	42	107.6	33.6	5	23.0	4.0
88	190.4	70.4	41	105.8	32.8	6	21.2	4.8
87	188.6	69.6	40	104.0	32.0	7	19.4	5.6
86	186.8	68.8	39	102.2	31.2	8	17.6	6.4
85	185.0	68.0	38	100.4	30.4	9	15.8	7.2
84	183.2	67.2	37	98.6	29.6	10	14.0	8.0
83	181.4	66.4	36	96.8	28.8	11	12.2	8.8
82	179.6	65.6	35	95.0	28.0	12	10.4	9.6
81	177.8	64.8	34	93.2	27.2	13	8.6	10.4
80	176.0	64.0	33	91.4	26.4	14	6.8	11.2
79	174.2	63.2	32	89.6	25.6	15	5.0	12.0
78	172.4	62.4	31	87.8	24.8	16	3.2	12.8
77	170.6	61.6	30	86.0	24.0	17	1.4	13.6
76	168.8	60.8	29	84.2	23.2	18	−0.4	14.4
75	167.0	60.0	28	82.4	22.4	19	2.2	15.2
74	165.2	59.2	27	80.6	21.6	20	4.0	16.0
73	163.4	58.4	26	78.8	20.8	21	5.8	16.8
72	161.6	57.6	25	77.0	20.0	22	7.6	17.6
71	159.8	56.8	24	75.2	19.2	23	9.4	18.4
70	158.0	56.0	23	73.4	18.4	24	11.2	19.2
69	156.2	55.2	22	71.6	17.6	25	13.0	20.0
68	154.4	54.4	21	69.8	16.8	26	14.8	20.8
67	152.6	53.6	20	68.0	16.0	27	16.6	21.6
66	150.8	52.8	19	66.2	15.2	28	18.4	22.4
65	149.0	52.0	18	64.4	14.4	29	20.2	23.2
64	147.2	51.2	17	62.6	13.6	30	22.0	24.0
63	145.4	50.4	16	60.8	12.8	31	23.8	24.8
62	143.6	49.6	15	59.0	12.0	32	25.6	25.6
61	141.8	48.8	14	57.2	11.2	33	27.4	26 4
60	140.0	48.0	13	55.4	10.4	34	29.2	27.2

TABLE CIV.—TEMPERATURE CONVERSION CENTIGRADE TO FAHRENHEIT.—(Continued).

C.	F.	R.	C.	F.	R.	C.	F.	R.
59	138.2	47.2	12	53.6	9.6	35	31.0	28.0
58	136.4	46.4	11	51.8	8.8	36	32.8	28.8
57	134.3	45.6	10	50.0	8.0	37	34.6	29.6
56	132.8	44.8	9	48.2	7.2	38	36.4	30.4
55	131.0	44.0	8	46.4	6.4	39	38.2	31.2
54	129.2	43.2	7	44.6	5.8	40	40.0	32.0

Fahrenheit degrees = 1.8 × Centigrade degrees + 32°.
Centigrade degrees = (Fahrenheit degrees) − 32° ÷ 1.8.

TABLE CV.—DECIMAL EQUIVALENTS OF FRACTIONS OF ONE INCH.

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1	1.

TABLE CVI.—TEMPERATURES, CENTIGRADE AND FAHRENHEIT FRACTIONAL EQUIVALENTS.

Degrees Centigrade	Degrees Fahrenheit
0.55	0.10
0.1	0.18
0.11	0.20
0.17	0.30
0.2	0.36
0.22	0.40
0.28	0.50
0.3	0.54
0.33	0.6
0.39	0.7
0.4	0.72
0.44	0.8
0.5	0.9
0.55	1.0
0.6	1.08
0.7	1.26
0.8	1.44
0.9	1.62
1.0	1.80

TABLE CVII.—PRESSURE EQUIVALENTS.

Unit	Equivalent Value in Other Units
1 lb. per sq. inch =	144 lbs. per square foot. 2.0355 in. of mercury at 32° F. 2.0416 in. of mercury at 62° F. 2.309 ft. of water at 62° F. 27.71 in. of water at 62° F.
1 atmosphere (14.7 lbs.) =	2116.3 lbs. per square foot. 33.947 ft. of water at 62° F. 30 in. of mercury at 62° F. 29.922 in. of mercury at 32° F.
1 inch of water at 62° F. =	0.0361 lb. per square inch. 5.196 lbs. per square foot. 0.0736 in. of mercury at 62° F.
1 inch of water at 32° F. =	5.2021 lbs. per square foot. 0.036125 lb. per square inch.
1 foot of water at 62° F. =	0.433 lb. per square inch. 62.355 lbs. per square foot. 0.883 in. of mercury at 62° F.
1 inch of mercury at 62° F. =	0.49 lb. per square inch. 70.56 lbs. per square foot. 1.132 ft. of water at 62° F. 13.58 ins. of water at 62° F.

TABLE CVIII.—POWER EQUIVALENTS.

Unit	Equivalent	Value in Other Units
1 Kilowatt Hour Equals=	1,000	Watt Hours
	1.34	Horse-Power Hours
	2,654,200	Foot-Pounds per Hour
	3,412	Heat Units per Hour
	367,000	Kilogram Meters
1 Horse-Power Equals =	746	Watts
	0.746	Kilowatt
	33,000	Foot-Pounds per Minute
	550	Foot-Pounds per Second
	2,545	Heat Units Per Hour
	42.4	Heat Units Per Minute
	0.707	Heat Units per Second
1 British Thermal Unit Equals =	1,055	Watt Seconds
	778	Foot-Pounds
	107.6	Kilogram Meters
	0.000293	Kilowatt Hour
	0.000393	Horse-Power Hour
1 Pound of Water Evaporated from and at 212 degrees Fahrenheit Equals =	0.283	Kilowatt Hour
	0.379	Horse-Power Hour
	970.4	Heat Units
	103,900	Kilogram Meters
	751,300	Foot-Pounds

TABLE CIX.—METRIC CONSTANTS.

EQUIVALENT OF LIQUIDS

One cubic meter of water	220.1	Imperial gallons.
One cubic meter of water	61028	Cubic inches.
One cubic meter of water	1000	Kilograms.
One cubic meter of water	1	Ton (approximate.)
One cubic meter of water	1000	Litres.
One cubic meter of water	2204.	pounds.
Column of water 1 foot high	0.434	pounds per square inch.
Column of water 1 meter high	1.43	pounds per square inch.
Column of water 2.31 feet high	1	pound per square inch.
One imperial gallon of water	277.274	Cubic inches.
One imperial gallon of water	10	pounds.
One cubic inch of water	0.3607	pounds.
One cubic foot of water	62.35	pounds.
One cubic foot of water	0.577	Hundredweight.
One cubic foot of water	0.028	Ton.
One pound of water	27.72	Cubic inches.
One pound of water	0.1	Imperial gallon.
One pound of water	0.4537	Kilograms.
One litre of water	0.22	Imperial gallon.
One litre of water	61	Cubic inches.
One litre of water	0.0353	Cubic feet.

TABLE CIX.—METRIC CONSTANTS.—(Continued).

METRICAL EQUIVALENTS (WEIGHTS AND MEASURES)

	Meters	Reciprocals
Inch	0.02539954	39.37079
Foot	0.3047945	3.280899
Yard	0.91438348	1.093633
Pole	5.029109	0.1988424
Chain	20.11644	0.0497106
Furlong	201.1644	0.004971
Mile	1609.3149	0.00062138

METRICAL EQUIVALENTS (WEIGHTS AND MEASURES)

1 Inch	2.54	centimeters.
1 Meter	3.281	feet.
1 Square inch	6.452	square centimeters.
1 Square meter	10.76	square feet..........1.196 square yard.
1 Cubic inch	16.39	centimeters.
1 Cubic meter	35.31	cubic feet.
1 Kilogram	2.205	pounds

TABLE CX.—AVERAGE TAP WATER TEMPERATURES OF (SUMMER) FOR CITIES OF UNITED STATES AND CANADA.

City	State	Deg. F.	Population
Youngstown	Ohio	90.8	132,358
Dallas	Tex.	90	158,976
Omaha	Neb.	86	191,601
Galveston	Tex.	85	42,000
Jacksonville	Fla.	82	91,543
Atlanta	Ga.	81	200,616
Augusta	Ga.	81	52,548
Cincinnati	Ohio	80	401,247
Birmingham	Ala.	80	172,270
New Orleans	La.	80	387,408
Kansas City	Mo.	77	345,000
Ottawa	Can.	77	112,000
St. Joseph	Mo.	77	77,735
Toledo	Ohio	76.5	243,109
Albany	N. Y.	76	113,344
Washington	D. C.	75.4	437,571
Nashville	Tenn.	75	118,342
Oklahoma City	Okla.	75	91,258
Charleston	S. C.	75	71,500
Providence	R. I.	74	275,000
Columbus	Ohio	74	237,031
Akron	Ohio	74	208,435
Richmond	Va.	74	158,700
Grand Rapids	Mich.	74	137,634
Springfield	Mass.	74	129,563
Decatur	Ill.	73	43,618
Mount Vernon	N. Y.	73	42,726
Pittsburgh	Pa.	72.5	588,193
Cleveland	Ohio	72	796,836
Minneapolis	Minn.	72	380,498
Worcester	Mass.	72	179,741
Pawtucket	R. I.	72	64,248
Buffalo	N. Y.	71	505,875
Waterbury	Conn.	71	91,410
Philadelphia	Pa.	70	1,823,158

TABLE CX.—AVERAGE TAP WATER TEMPERATURES—(SUMMER) FOR CITIES OF UNITED STATES AND CANADA.—(Continued.)

City	State	Deg. F.	Population
Louisville	Ky.	70	234,891
Oakland	Cal.	70	216,361
Dayton	Ohio	70	153,830
Paterson	N. J.	70	135,856
Winnipeg	Can.	70	135,430
Cambridge	Mass.	70	109,450
Erie	Pa.	70	93,372
Troy	N. Y.	70	78,000
Little Rock	Ark.	70	64,997
Mobile	Ala.	70	60,124
Woonsocket	R. I.	70	43,496
Charlestown	W. Va.	70	39,608
Boston	Mass.	69	749,923
Rochester	N. Y	69	295,750
New Bedford	Mass.	69	121,217
Somerville	Mass.	69	93,033
Malden	Mass.	69	49,103
Utica	N. Y.	68	94,136
Cedar Rapids	Iowa	68	45,566
Lexington	Ky.	67.8	41,534
Detroit	Mich.	67	993,739
Montreal	Can.	67	466,197
Milwaukee	Wis.	67	457,147
St. John	N. B.	65.5	60,000
New York	N. Y.	65	5,621,151
Brooklyn	N. Y.	65	
St. Paul	Minn.	65.5	235,595
Des Moines	Iowa	65	126,468
San Francisco	Cal.	65	508,410
New Haven	Conn.	65	162,390
Johnstown	Pa.	65	67,327
Jackson	Mich.	65	48,374
Pasadena	Cal.	65	45,334
Los Angeles	Cal.	62	575,490
Gary	Ind.	62	55,453
Tacoma	Wash.	60	96,965
Elizabeth	N. J.	60	95,682
Lawrence	Mass.	60	94,270
Allentown	Pa.	60	73,502
Portland	Maine	60	69,000
Lincoln	Neb.	60	54,934
Roanoke	Va.	60	50,842
Seattle	Wash.	60	315,362
Rockford	Ill.	58	65,651
Springfield	Ohio	58	60,840
Haverhill	Mass.	58	53,884
East Orange	N. J.	58	50,587
Lowell	Mass.	56	112,479
Davenport	Iowa	56	56,727
Duluth	Minn.	55	98,917
Hamilton	Can.	55	81,881
Peoria	Ill.	54	76,121
Spokane	Wash.	52	104,204
Sioux City	Iowa	51	71,227
Portland	Ore.	50	258,288
Salt Lake City	Utah	50	118,110
Galveston	Tex.	80	42,000
Jacksonville	Fla.	76	91,543
Youngstown	Ohio	68.7	132,358
Augusta	Ga.	66	52,548
New Orleans	La.	62	387,408
Birmingham	Ala.	65	172,270
Charleston	S. C.	65	74,500
Cincinnati	Ohio	62	401,247
Kansas City	Mo.	62	345,000
Atlanta	Ga	62	200,616
Philadelphia	Pa.	61	1,823,158
Washington	D C	60.5	437,571

TABLE CX.—AVERAGE TAP WATER TEMPERATURES (WINTER) FOR CITIES OF UNITED STATES AND CANADA.—(Continued.)

City	State	Deg. F.	Population
Los Angeles	Cal.	60	575,490
Dayton	Ohio	60	153,830
Louisville	Ky.	60	234,891
Omaha	Neb.	60	191,601
Nashville	Tenn.	60	118,342
Oklahoma City	Okla.	60	91,258
Troy	N. Y.	60	78,000
Mobile	Ala.	60	60,124
Springfield	Mass.	60	129,563
Roanoke	Va.	60	50,842
New Haven	Conn.	58	162,390
Des Moines	Iowa	58	126,468
Rockford	Ill.	58	65,651
East Orange	N. J.	58	50,710
Lexington	Ky.	57.4	41,534
San Francisco	Cal.	57	508,410
Allentown	Pa.	57	73,502
Terre Haute	Ind.	57	66,082
New Brunswick	N. J.	57	24,000
Pasadena	Cal.	57	45,334
Springfield	Ohio	57	60,840
Cleveland	Ohio	56	796,836
Toledo	Ohio	56	243,109
Winnipeg	Can.	56	135,430
Albany	N. Y.	56	113,344
Columbus	Ohio	56	237,031
Davenport	Iowa	56	56,727
New York	N. Y.	55	5,621,151
Brooklyn	N. Y.	55	
Lincoln	Neb.	55	54,934
Akron	Ohio	55	208,435
Pawtucket	R. I.	55	64,248
Utica	N. Y.	55	94,136
Oakland	Cal.	55	216,361
Cedar Rapids	Iowa	55	45,566
Grand Rapids	Mich.	55	137,634
Lawrence	Mass.	55	94,270
New Bedford	Mass.	55	121,217
Mt. Vernon	N. Y.	55	42,726
Boston	Mass.	54	749,923
Ottawa	Can.	54	112,000
St. Joseph	Mo.	54	77,735
Malden	Mass.	54	49,103
Minneapolis	Minn.	54	380,498
St. Paul	Minn.	54	235,595
Waterbury	Conn.	54	91,410
Lowell	Mass.	54	112,479
Sommerville	Mass.	53.5	93,033
Providence	R. I.	53	275,000
Erie	Pa.	53	93,372
Decatur	Ill.	53	43,618
Pittsburgh	Pa.	52.8	588,193
Buffalo	N. Y.	52	505,875
Gary	Ind.	52	55,433
Montreal	Can.	51	466,197
Rochester	N. Y.	51	295,750
St. John	N. B.	51	60,000
Detroit	Mich.	50	993,739
Elizabeth	N. J.	50	95,682
Ft. Wayne	Ind.	50	86,549
Little Rock	Ark.	50	64,997
Johnstown	Pa.	50	67,327
Cambridge	Mass.	50	109,450
Portland	Maine	50	69,000
Paterson	N. J.	50	33,856
Spokane	Wash.	50	104,204
Woonsocket	R. I.	50	43,496
Milwaukee	Wis.	50	457,147
Seattle	Wash.	49	315,362

TABLE CX.—AVERAGE TAP WATER TEMPERATURES (WINTER) FOR CITIES OF UNITED STATES AND CANADA.—(Contined.)

City	State	Deg. F.	Population
Council Bluffs	Iowa	49	36,162
Sioux City	Iowa	49	71,227
Superior	Wis.	47	39,674
Salt Lake City	Utah	45	118,110
Duluth	Minn.	45	98,917
Jackson	Mich.	45	48,374
Hamilton	Can.	45	81,881
Portland	Ore.	42	258,288
Haverhill	Mass.	40.7	53,884
Tacoma	Wash.	40.5	96,965
Charleston	S. C.	40	71,500

TABLE CXI.—DENSITY AND WEIGHT OF WATER.
(Rosetti Table and D. K. Clark Manual).

Temperature Deg. F.	Relative Density	Weight per Cubic Foot
32	0.99987	62.416
35	0.99996	62.421
39.3	1.00000	62.424
40	0.99999	62.423
43	0.99997	62.422
45	0.99992	62.419
50	0.99975	62.408
55	0.99946	62.390
60	0.99907	62.366
70	0.99802	62.300
80	0.99669	62.217
90	0.99510	62.118
100	0.99318	61.998
110	0.99105	61.865
120	0.98870	61.719
130	0.98608	61.555
140	0.98338	61.386
150	0.98043	61.203
160	0.97729	61.006
170	0.97397	60.799
180	0.97056	60.586
190	0.96701	60.365
200	0.96333	60.135
212	0.95865	58.843
230		59.4 (Sat. Pressure)
250		58.7
270		58.2
290		57.6
298		57.3
338		56.1
366		55.3
390		54.5

TABLE CXII.—WEIGHT OF VARIOUS SUBSTANCES PER CUBIC FOOT.

Name	Pounds	Name	Pounds
Mercury	847.7	Tobacco	80.
Brine	77.4	Oil, average	56
Milk	64.3	Eggs	25
Sea water	64.05	Fruit	22
Pure water	62.425	Butter	58.7
Linseed oil	58.7	Fat	58.5
Whale oil	57.4	Oak, white	48
Sugar	100.37	Pine, yellow	38
Soap	66.9	Vinegar	67.5
Salt	45.	Beef fat	57.68
Dry fruits	45.	Hog Fat	58.50
Lime	50.	Hard coal	85
Olive oil	57.1	Stone	118
Turpentine	54.3	Masonry	143
Petroleum	54.9	Sand	110
Naphtha	53.1	Cast iron	450.54
Alcohol	57.4	Wrought iron	480
Benzine	53.1	Brass	511
Wine	62	Charcoal	18
Ash	34.3	Lead	709.7
Ice	57.5	Beer	64.62
Earth	93	Snow	5.2
Soft coal	80		

TABLE CXIII.—VOLUME AND WEIGHT OF DRY AIR AT DIFFERENT TEMPERATURES.

Under a Constant Atmosp. Pres. of 29.92 ins. of mercury, the vol. at 32° Fahr. being 1.

Temp. Deg. F.	Volume	Weight per cu. ft.
0	.935	0.0864
12	.960	0.0842
22	.980	0.0824
32	1.000	0.0807
42	1.020	0.0791
52	1.041	0.0776
62	1.061	0.0761
72	1.082	0.0747
82	1.102	0.0733
92	1.122	0.0720
102	1.143	0.0707
112	1.163	0.0694
122	1.184	0.0682
132	1.204	0.0671
142	1.224	0.0659
152	1.245	0.0649
162	1.265	0.0638
172	1.285	0.0628
182	1.306	0.0618
192	1.326	0.0609

*From Hoffman's Handbook for Heating and Ventilating Engineers, published by McGraw Hill Co., Inc.

TABLE CXIV.—SPECIFIC HEATS, WATER AT 32° F. = 1.
(Frick Co.)

Name	Spec. Heat	Name	Spec. Heat
Cast iron	0.130	Coal	0.241
Brass	0.094	Sulphur	0.202
Mercury	0.033	Coke	0.203
Tin	0.056	Alcohol	0.659
Zinc	0.095	Oil	0.310
Chalk	0.215	Vinegar	0.920
Stone	0.270	Strong brine	0.700
Masonry	0.200	Ice	0.504
Oak wood	0.570	Water	1.000
Pine	0.650	Air	0.238
Glass	0.194		

TABLE CXV.—COEFFICIENTS OF EXPANSION FOR VARIOUS SUBSTANCES.

Substance	Coefficient of Linear Expansion in inches per Deg. F.
Aluminum	0.00001140
Brass	0.00001040
Brick	0.00000306
Cement and Concrete	from 0.00000550 to 0.00000780
Copper	0.00000961
Glass	from 0.00000399 to 0.00000521
Gold	0.00000841
Granite	0.00000460
Iron, cast	0.00000587
Iron, wrought	0.00000677
Lead	0.00001580
Marble	0.00000400
Masonry	from 0.00000206 to 0.00000490
Mercury	0.00000334
Platinum	0.00000494
Porcelain	0.00000200
Sandstone	from 0.00000400 to 0.00000670
Steel, untempered	0.00000599
Steel, tempered	0.00000702
Tin	0.00001160
Wood, pine	0.00000276
Zinc	0.00001634

TABLE CXVI.—SPECIFIC HEATS OF GASES.

Name of gas	Specific Heat	
	Constant Pressure	Volume Constant
Air	0.23751	0.16902
Carbon dioxide	0.21700	0.15350
Carbon monoxide	0.24500	0.17580
Hydrogen	3.40900	2.41226
Nitrogen	0.24380	0.17273
Oxygen	0.21751	0.15507

TABLE CXVII.—COEFFICIENTS OF EXPANSION AND COEFFICIENTS OF TRANSMISSION OF SOLIDS AND LIQUIDS.

Substance	Coefficient of Expansion	Coefficient of Transmission
Antimony	0.00000602	0.00022
Copper	0.00000955	0.00404
Gold	0.00001060	....
Wrought Iron	0.00000895	0.00089
Glass	0.00000478	0.0000008
Cast Iron	0.00000618	0.000659
Lead	0.00001580	0.00045
Platinum	0.00000530	....
Silver	0.00001060	0.00610
Tin	0.00001500	0.00084
Steel (soft)	0.00000600	0.00062
Steel (hard)	0.00000689	0.00034
Nickel steel 36%	0.00000003	....
Zinc	0.00001633	0.00170
Brass	0.00001043	0.00142
Ice	0.00000375	0.000024
Sulphur	0.00006413	....
Charcoal	0.00007860	0.000002
Aluminum	0.00002313	0.00203
Phosphorus	0.00012530	....
Water	0.00008806	0.000008
Mercury	0.00003333	0.00011
Alcohol (absolute)	0.00015151	0.000002

*From Hoffman's Handbook for Heating and Ventilating Engineers, published by McGraw Hill Co., Inc.

TABLE CXVIII.—COEFFICIENT OF EXPANSION AND COEFFICIENTS OF HEAT TRANSMISSION OF GASES.*

Substance	Pressure Constant	Constant Volume	Coefficient of Cubical Expansion at 1 Atmosphere	Coefficient of Transmission
Air	0.23751	0.16847	0.003671	0.0000015
Oxygen	0.21751	0.15507	0.003674	0.0000012
Hydrogen	3.40900	2.41226	0.003669	0.0000012
Nitrogen	0.24380	0.17273	0.003668	0.0000012
Superheated steam	0.4805	0.346	0.003726	....
Carbonic acid	0.2170	0.1535	....	0.00000122

*From Hoffman's Handbook for Heating and Ventilating Engineers, published by McGraw Hill Co., Inc.

TABLE CXIX.—STRENGTH OF MATERIALS.

Material	Elastic Limit			Ultimate Strength			Factory of Safety		
	Tension	Comp.	Shear	Tension	Comp.	Shear	Steady	Variable	Shock
Brick					3000	1000	15	25	30
Stone					6000	1500	15	25	30
Timber	3000	3000	L. 600 T. 3000	10000	8000	L. 600 T. 3000	8	15	15
Cast Iron	6000	20000	20000	15000	80000	20000	6	15	20
Wrought Ir.	25000	25000	40000	50000	50000	40000	4	8	10
Struct. Stl.	35000	35000	50000	60000	60000	50000	4	8	10
Cast Stl.	50000	50000	80000	70000	70000	60000	5	8	15

TABLE CXX.—PHYSICAL CONSTANTS OF METALS.

Metal	Specific Gravity	Specific Heat	Melting Point Degrees F.
Aluminum	2.56	0.218	1216
Antimony	6.71	0.051	1166
Arsenic	5.67	0.081	1472
Barium	3.78	0.047	1562
Bismuth	9.80	0.031	518
Cadmium	8.60	0.056	610
Caesium	1.87	0.048	79
Calcium	1.57	0.170	1481
Cerium	6.68	0.045	1152
Chromium	6.50	0.120	2741
Cobalt	8.50	0.103	2714
Columbium	12.70	0.071	....
Copper	8.93	0.093	1981
Gallium	5.90	0.079	86
Glucinum	1.93	0.621	....
Gold	19.32	0.031	1945
Indium	7.42	0.057	311
Iridium	22.42	0.033	4172
Iron	7.86	0.110	2768
Lanthanum	6.20	0.045	1490
Lead	11.37	0.031	621
Lithium	0.54	0.941	367
Magnesium	1.74	0.250	1204
Manganese	8.00	0.120	2237
Mercury	13.59	0.032	—38
Molybdenum	8.60	0.072	4532
Nickel	8.80	0.108	2642
Osium	22.48	0.031	4530
Palladium	11.50	0.059	2822
Platinum	21.50	0.032	3191
Potassium	0.86	0.170	144
Rhodium	12.10	0.058	3452
Rubidium	1.53	0.077	100
Ruthenium	12.26	0.061	3270
Silver	10.53	0.056	1762
Sodium	0.97	0.290	207
Strontium	2.54	....	1472
Tantalum	10.80	0.036	5252
Tellurium	6.25	0.049	825
Thallium	11.85	0.033	578
Thorium	11.10	0.028	....
Tin	7.29	0.055	450
Titanium	3.54	0.130	3362
Tungsten	19.10	0.034	5432
Uranium	18.70	0.028	4352
Vanadium	5.50	0.125	3182
Yttrium	3.80	....	....
Zinc	7.15	0.094	786
Zirconcium	4.15	0.066	2700

TABLE CXXI.—DIMENSIONS OF STANDARD PIPE.

Diameter.			Thickness, in.	Circumference		Transverse areas.			Length of pipe per sq. ft. of		Length of pipe containing one cu. ft., ft.	Wt. per ft. of length, lbs.	No. of thr'ds per in. of screw.	Contents in gals. per ft. of length,	Wt. of water per ft. of length. lbs.
Nominal, internal, in.	Actual external, in.	Actual internal, in.		External, in.	Internal, in.	External, sq. in.	Internal, sq. in.	Metal. sq. in.	External surface, ft.	Internal surface, ft.					
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27	.0006	.005
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18	.0026	.021
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18	.0057	.047
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14	.0102	.085
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14	.0230	.190
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½	.0408	.349
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½	.0638	.527
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½	.0918	.760
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½	.1632	1.356
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8	.2550	2.116
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8	.3673	3.049
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8	.4998	4.155
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8	.6528	5.405
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.34	8	.8263	6.851
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8	1.020	8.500
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8	1.469	12.312
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8	1.999	16.662
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8	2.611	21.750
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8	3.300	27.500
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8	4.081	34.000
11	12.	11.25	.375	37.690	35.343	113.098	99.402	13.696	.318	.339	1.456	45.95	8	......	.....
12	12.75	12	.375	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8	......	.....
..	14.	13.25	.375	42.982	41.626	153.938	137.88	16.051	.273	.288	1.04	53.922	8	......	.....
..	15.	14.25	.375	47.124	44.768	176.715	159.485	17.23	.255	.268	.903	57.893	8	......	.....
..	16.	15.25	.375	50.265	47.909	201.062	182.655	18.407	.239	.250	.788	61.77	8	......	.....
..	18.	17.25	.375	56.549	54.192	254.47	233.706	20.764	.212	.221	.616	69.66	..	......	.....
..	20.	19.25	.375	62.832	60.476	314.16	291.04	23.12	.191	.198	.495	77.57	..	......	.....
..	22.	21.25	.375	69.115	66.759	380.134	354.657	25.477	.174	.179	.406	85.47	..	......	.....
..	24.	23.25	.375	75.398	73.042	452.39	424.558	27.832	.159	.164	.339	93.37	..	......	.....

TABLE CXXII.—DIMENSIONS OF EXTRA AND DOUBLE EXTRA STRONG PIPE.

Diameter.			Thickness, in.	Nearest wire gauge, No.	Circumference.		Transverse area.			Length of pipe in ft. per sq. ft. of		Nominal wt. in lbs. per ft.
Nominal internal, in.	Actual external, in.	Actual internal, in.			External, in.	Internal, in.	External, sq. in.	Internal, sq. in.	Metal. sq. in.	External surface.	Internal surface.	
⅛	.405	.205	.1	12½	1.272	.644	.129	.033	.086	9.433	18.632	.29
¼	.54	.294	.123	11	1.696	.924	.229	.068	.161	7.075	12.986	.54
⅜	.675	.421	.127	10½	2.121	1.323	.358	.139	.219	5.657	9.07	.74
½	.84	.542	.149	9	2.639	1.703	.554	.231	.323	4.547	7.046	1.09
¾	1.05	.736	.157	8½	3.299	2.312	.866	.452	.414	3.637	5.109	1.39
1	1.315	.951	.182	7	4.131	2.988	1.358	.71	.648	2.904	4.016	2.17
1¼	1.66	1.272	.194	6½	5.215	3.996	2.164	1.271	.893	2.301	3.003	3.
1½	1.9	1.494	.203	6	5.969	4.694	2.835	1.753	1.082	2.01	2.556	3.63
2	2.375	1.933	.221	5	7.461	6.073	4.43	2.935	1.495	1.608	1.975	5.02
2½	2.875	2.315	.28	2	9.032	7.273	6.492	4.209	2.283	1.328	1.649	7.67
3	3.5	2.892	.304	1	10.996	9.085	9.621	6.569	3.052	1.091	1.328	10.25
3½	4.	3.358	.321	0	12.566	10.549	12.566	8.856	3.71	.955	1.137	12.47
4	4.5	3.818	.341	0	14.137	11.995	15.904	11.449	4.455	.849	1.	14.97
5	5.563	4.813	.375	00	17.477	15.120	24.306	18.193	6.12	.687	.793	20.54
6	6.625	5.75	.437	000	20.813	18.064	34.472	25.967	8.505	.577	.664	28.58

DOUBLE EXTRA STRONG PIPE—Table of Standard Dimensions.

½	.84	.244	.298	1	2.639	.766	.554	.047	.507	4.547	15.667	1.7
¾	1.05	.422	.314	1	3.299	1.326	.866	.139	.727	3.637	9.049	2.44
1	1.315	.587	.364	00	4.131	1.844	1.358	.271	1.087	2.904	6.508	3.65
1¼	1.66	.885	.388	00	5.215	2.78	2.164	.615	1.549	2.304	4.317	5.2
1½	1.9	1.088	.406	000	5.969	3.418	2.835	.93	1.905	2.01	3.511	6.4
2	2.375	1.491	.442	0000	7.461	4.684	4.43	1.744	2.686	1.608	2.561	9.02
2½	2.875	1.755	.560	9/16−	9.032	5.513	6.492	2.419	4.073	1.328	2.176	13.68
3	3.5	2.284	.608	⅝−	10.996	7.175	9.621	4.097	5.524	1.091	1.672	18.56
3½	4.	2.716	.642	⅝+	12.566	8.533	12.566	5.794	6.772	.955	1.406	22.75
4	4.5	3.136	.682	11/16−	14.137	9.852	15.904	7.724	8.18	.849	1.217	27.48
5	5.563	4.063	.75	¾	17.477	12.764	24.306	12.965	11.34	.687	.940	38.12
6	6.625	4.875	.875	⅞	20.813	15.315	34.472	18.666	15.896	.577	.784	53.11

TABLE CXXIII.—COPPER TUBES.
Weight per Lineal Foot.

Gauge No.	13	14	15	16	17	18	19	20	21	22
Wall Thickness Inches	0.095	0.083	0.072	0.065	0.058	0.049	0.042	0.035	0.032	0.028
Outside Diameter of Tube Inches										
1/8				0.048	0.047	0.045	0.042	0.038	0.036	0.033
3/16			0.101	0.097	0.091	0.082	0.073	0.065	0.060	0.054
1/4	0.178	0.168	0.155	0.146	0.135	0.120	0.106	0.091	0.084	0.076
5/16	0.250	0.231	0.210	0.195	0.178	0.156	0.138	0.118	0.109	0.097
3/8	0.322	0.294	0.265	0.245	0.223	0.193	0.169	0.144	0.133	0.118
7/16	0.395	0.357	0.319	0.293	0.267	0.231	0.202	0.171	0.157	0.139
1/2	0.466	0.420	0.374	0.342	0.311	0.268	0.233	0.197	0.182	0.160
5/8	0.610	0.546	0.483	0.441	0.399	0.342	0.297	0.250	0.230	0.203
3/4	0.754	0.672	0.591	0.540	0.486	0.416	0.360	0.303	0.278	0.245
1	1.04	0.92	0.81	0.73	0.66	0.57	0.48	0.408	0.376	0.330

NOTE: Stubs or Birmingham gauge used.

Formula for determining the proper thickness of copper tubing is given as follows:

$$T = \frac{P \times D}{6{,}000} + .0625$$

Where T = thickness in inches
P = working pressure
D = Inside diameter of the tube in inches

This was prescribed by Board of Supervising Inspectors of Steamboats. (1911).

TABLE CXXIV.—SHEET METAL DIMENSIONS AND WEIGHTS.
Wt. per sq. ft. in lbs.

Decimal Gauge	Iron 480 lbs. per cu. ft.	Steel 489.6 lbs. per cu. ft.	U. S. Gauge numbers
0.002	0.08	0.082	
0.004	0.16	0.163	
0.006	0.24	0.245	38–39
0.008	0.32	0.326	34–35
0.010	0.40	0.408	32
0.012	0.48	0.490	30–31
0.014	0.56	0.571	29
0.016	0.64	0.653	27–28
0.018	0.72	0.734	26–27
0.020	0.80	0.816	25–26
0.022	0.88	0.898	25
0.025	1.00	1.020	24
0.028	1.12	1.142	23
0.032	1.28	1.306	21–22
0.036	1.44	1.469	20–21
0.040	1.60	1.632	19–20
0.045	1.80	1.836	18–19
0.050	2.00	2.040	18
0.055	2.20	2.244	17
0.060	2.40	2.448	16–17
0.065	2.60	2.652	15–16
0.070	2.80	2.856	15
0.075	3.00	3.060	14–15
0.080	3.20	3.264	13–14
0.085	3.40	3.468	13–14
0.090	3.60	3.672	13–14
0.095	3.80	3.876	12–13
0.100	4.00	4.080	12–13
0.110	4.40	4.488	12
0.125	5.00	5.100	11
0.135	5.40	5.508	10–11
0.150	6.00	6.120	9–10
0.165	6.60	6.732	8–9
0.180	7.20	7.344	7–8
0.200	8.00	8.160	6–7
0.220	8.80	8.976	4–5
0.240	9.60	9.792	3–4
0.250	10.00	10.200	3

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TOPICAL INDEX.

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Hull, Harry Blair, 1890-
Household refrigeration; a complete treatise on the principles, types, construction, and operation of both ice and mechanically cooled domestic refrigerators, and the use of ice and refrigeration in the home, by H. B. Hull ... 3d ed., rev. and enl. Chicago, Nickerson & Collins co. [c1927]
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